78th Congress, 1st Session - - - - - House Document No. 266

OHIO RIVER POLLUTION CONTROL

LETTER

FROM

THE ACTING SECRETARY OF WAR

TRANSMITTING

A LETTER FROM THE CHIEF OF ENGINEERS, UNITED STATES ARMY, DATED MAY 4, 1943, FORWARDING A REPORT, TOGETHER WITH ACCOMPANYING PAPERS AND ILLUSTRATIONS, ON A SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL, AUTHORIZED BY SECTION 5 OF THE RIVER AND HARBOR ACT APPROVED AUGUST 26, 1937

IN TWO PARTS
(Three Volumes)

PART ONE

REPORT OF THE OHIO RIVER COMMITTEE

AUGUST 27, 1943.—Referred to the Committee on Rivers and Harbors and ordered to be printed, with 257 illustrations

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UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1944

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(Part I consists of the report of the Ohio River Committee)

(Part II consists of the report of the United States Public Health Service)

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War Department,
Washington, July 21, 1943.

The Speaker of the House of Representatives.

My Dear Mr. Speaker: I am transmitting herewith a letter dated May 4, 1943, from the Chief of Engineers, United States Army, forwarding a report dated April 20, 1943, from the Ohio River Committee, together with accompanying papers and illustrations, on the survey of the Ohio River and its tributaries authorized by section 5 of the River and Harbor Act approved August 26, 1937, to ascertain what pollutive substances are being desposited, directly or indirectly, therein and the sources and extent of such deposits, and with a view to determining the most feasible method of correcting and eliminating the pollution of these streams. I concur in the findings and recommendations of the Chief of Engineers and the committee.

The Under Secretary of War advises that the project as recommended is not essential to, nor of indicated value in the war effort and he points out that the mine-sealing program, if adopted, would require substantial amounts of critical materials, manpower, and construction equipment, without being a necessity to the prosecution of the war program. He further states that there is no objection to the submission of the report, but he does not approve of the submission of any estimate of appropriation for construction, or the initiation of any construction of this project until after the war.

The Bureau of the Budget has been consulted and advises that, while there would be no objection to the presentation of the proposed report to the Congress, the submission during the present emergency of any estimate of appropriation for Federal participation in the program therein recommended would not be in accord with the program of the President, in the absence of further evidence of the need of undertaking any part of that program in conjunction with the war effort; and that no commitment is made at this time as to the relationship with the program of the President of the proposed degree of Federal participation in the recommended pollution abatement program.

Sincerely yours,

Robert P. Patterson,
Acting Secretary of War.

REPORT UPON SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, May 4, 1943.

Subject: Ohio River pollution control.

To: The Secretary of War.

1. I am forwarding herewith for transmission to Congress the report of the Ohio River Committee with accompanying papers and illustrations on the survey of the Ohio River and its tributaries for pollution control, authorized by section 5 of the River and Harbor Act approved August 26, 1937. The report is in two parts, part I, the Ohio River Committee's report, and part II, the Public Health Service's report.

2. In accordance with the request of the President, the Secretary of War and the Secretary of the Treasury joined in the appointment of a committee designated as the Ohio River Committee to conduct the survey. The members of this committee are Maj. Gen. Thomas M. Robins, Assistant Chief of Engineers; Mr. Ralph E. Tarbett, Sanitary Engineer Director, United States Public Health Service; and Dr. Abel Wolman, Consulting Engineer, Baltimore, Md.

3. This survey is the most complete and comprehensive examination ever made into the sanitary conditions of a major river and its tributaries, draining an area highly developed commercially, industrially, and agriculturally. About 5 years were required to obtain and analyze the voluminous field data necessary for a sound study of the complicated problems involved, to consider the technical, financial, and other associated questions, and to develop a plan for remedial improvements. The Corps of Engineers and the Public Health Service were in full collaboration at all times on this comprehensive pollution report.

4. After due consideration of this report, I concur in the recommendations of the Ohio River Committee.

E. REYBOLD,
Major General,
Chief of Engineers.

REPORT UPON SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

OHIO RIVER COMMITTEE,
Washington, D. C., April 20, 1943.

Subject: Report upon survey of the Ohio River and its tributaries for pollution control.

To: The Secretary of War.

[Through the Chief of Engineers, U. S. Army, Washington, D. C.]

I. SYLLABUS

1. Practically all streams in the Ohio River Basin are polluted by domestic and industrial wastes, while some have severe corrosive characteristics imparted to them by acid mine drainage. The Ohio River proper is polluted to such an extent that 30 public sources of water supply serving about 1,660,000 people are endangered. The pollution of a number of the tributaries is as severe as, or even more severe than, the worst reaches on the main Ohio River, but the effect of such pollution on the tributaries is for the most part local and has little importance on the Ohio River proper. The findings indicate that sufficient control and abatement of pollution should be undertaken, at the earliest practicable date, to protect endangered sources of water supply both on the Ohio River proper and on the tributaries. A complete, well-balanced program, yielding maximum benefits attainable at reasonable and justifiable costs, is presented with the recommendation that it be completed in 15 years.

2. The principal obstacle to the abatement of pollution is the actual financing of the necessary facilities. Active support and participation on the part of the States and the Federal Government are indicated and needed as a stimulus if any large and comprehensive program for the abatement of pollution is to be undertaken and properly completed in the Ohio River Basin. A comprehensive program of research and education is also needed to discover new and more economical methods of waste treatment and recovery, and to inform the public of the necessity for the abatement of pollution.

3. No definite action toward the enforcement of pollution abatement should be undertaken by the Federal Government unless all State and interstate action fails to secure the proper control. The tangible and intangible benefits accruing to the Federal Government in protecting health and general welfare in the Ohio River Basin, as well as benefits accruing in the reduction of damage to commerce and navigation and the general security obtained by the abatement of pollution, justifies Federal financial aid. This aid should be in the form of grants (say 35 percent of the construction cost of abatement projects) and loans to States, their political subdivisions, or municipalities.

4. It is recommended:

(*a*) That the proposed Ohio River Valley Water Sanitation Compact be modified and vitalized to provide an improved means for uniform and effective control of all pollution interestate in its effect, and that when this has been accomplished the United States Public Health Service be authorized to participate in an indicated construction program for abatement of pollution in the Ohio River Basin.

(*b*) That the United States Public Health Service conduct a program of research and education.

(c) That the United States Bureau of Mines continue the program for sealing abandoned mines, and otherwise reducing acid pollution by mine drainage.

5. While it is impracticable to formulate accurate estimates of the cost of individual features of the above program, it is believed that the total cost will be about $200,000,000, less than one-half of which would be a permanent charge against Federal funds.

6. In addition to the foregoing specific remedial measures, considerable benefit can be obtained by operating existing and future reservoirs so as to obtain the maximum low flow control for dilution of acid and organic pollution.

II. Authority and Preface

7. *Authority for report.*—The authority for this report is contained in the River and Harbor Act approved August 26, 1937; section 5 of which reads as follows:

> Sec. 5. That the Secretary of War is hereby authorized and directed to cause a survey to be made of the Ohio River and its tributaries to ascertain what pollutive substances are being deposited, directly or indirectly, therein and the sources and extent of such deposits, and with a view to determining the most feasible method of correcting and eliminating the pollution of these streams.
>
> The survey herein authorized shall include comprehensive investigations and studies of the various problems relating to stream pollution and its prevention and abatement. In making these investigations and studies, and in the development and formulation of corrective plans, the Secretary of War may, with the approval of the Secretary of the Treasury, secure the cooperation and assistance of the Public Health Service, and may allot funds from the appropriation hereinafter designated to pay for such cooperation and assistance. The survey shall be completed as soon as practicable after the passage of this Act, and the Secretary of War shall report the results thereof to the Congress, together with such recommendations for remedial legislation as he deems advisable.
>
> The cost of the survey, and such incidental expenses as may be necessary in connection therewith, shall be paid from appropriations heretofore or hereafter made for examinations, surveys, and contingencies of rivers and harbors.

8. *Formation of Ohio River Committee.*—Upon signing the above-mentioned river and harbor bill, the President asked the Secretary of War and the Secretary of the Treasury to join in the appointment of a committee of three to conduct the survey, the committee to consist of an Army engineer, a representative of the Public Health Service, and a non-Government expert on stream-pollution problems. In response, the Secretary of War designated Brig. Gen. Max C. Tyler to represent the Corps of Engineers; the Secretary of the Treasury designated Senior Sanitary Engineer Ralph E. Tarbett to represent the Public Health Service; and Dr. Abel Wolman, Consulting Engineer, Baltimore, Md., was chosen as the third member of the committee, referred to herein as the "Ohio River Committee." Maj. Gen. Thomas M. Robins later assumed committee membership in place of General Tyler upon assignment of the latter to duty as president of the Mississippi River Commission.

9. *Conduct of survey by the United States Public Health Service and the Army Engineers.*—The survey was conducted by the United States Public Health Service for and with the assistance of the Corps of Engineers, United States Army, under the general direction of the Ohio River Committee. The Public Health Service undertook all field sanitary surveys and laboratory studies and developed a suggested plan of corrective measures. The Corps of Engineers made the necessary hydrometric surveys (river discharge and velocity measurements,

studies for augmenting low-water flows by reservoir releases, etc.). Both agencies were in constant collaboration throughout the study. The report of the United States Public Health Service on this survey, published as part II, forms the basis for the report by the Ohio River Committee.

10. *Scope.*—This survey is the most complete and comprehensive examination ever made into the sanitary condition of a major river and its tributaries draining an area highly developed commercially, industrially, and agriculturally. About 4 years were required to obtain and analyze the voluminous field data necessary for a sound study of the complicated problems involved, to study the technical, financial, administrative, and other associated questions, and to develop the plan for remedial improvements recommended herein. The cost of the investigation was approximately $600,000.

11. *Acknowledgments.*—The Committee desires to acknowledge the full cooperation received from the Public Health Service and the Corps of Engineers. Other Federal agencies from which assistance was obtained on special phases of the work include the Fish and Wildlife Service, the United States Geological Survey, the Bureau of the Census, the United States Bureau of Mines, the Soil Conservation Service, and the National Resources Planning Board. The various State health departments within the Ohio River Basin rendered valuable aid by making various data available, by providing office space to field personnel, and in numerous other ways. The Health and Safety Section of the Tennessee Valley Authority provided similar assistance. Municipal officials, water and sewage treatment plant operators, and industrial officials aided by furnishing data on plant operations and wastes-discharged. In numerous instances, municipalities furnished facilities to the mobile laboratories without charge. The cities of Cincinnati and Louisville made available the results of consulting engineers' studies of their waste-disposal problems. The assistance of various engineers in private practice, equipment manufacturers, trade associations, universities, technical schools, and individuals was also of great value.

12. *Arrangement of report.*—This report has been divided into two parts; that is, part I, the report of the Ohio River Committee, and part II, the report of the United States Public Health Service to the Ohio River Committee. For a summary of the content of each part, including lists of the tables appendixes, plates, maps, and charts therein, see the table of contents at the beginning of each.

III. Prior Reports

13. The extent of the Ohio River Basin and the pollution problems therein and the interest of sanitary engineers, public-health officials, and others, have resulted in numerous studies of stream pollution in the area. These studies generally have been applicable to restricted localities and tributary streams only. They have not been listed herein.

14. A report on prior investigations by the Public Health Service of pollution of the Ohio River is published under the title, "A Study of the Pollution and Natural Purification of the Ohio River," as follows:

(*a*) For a survey during the period January 1, 1914, to December 31, 1916:

(1) I. The Plankton and Related Organizms, by W. C. Purdy (Public Health Bulletin No. 131, December 1922).

(2) II. Report of Surveys and Laboratory Studies, by Frost, Hoskins, Tarbett, and Streeter (Public Health Bulletin No. 143, July 1924).

(3) III. Factors Concerned in the Phenomena of Oxidation and Reaeration, by E. B. Phelps (Public Health Bulletin No. 146, February 1925).

(*b*) For a survey during the period November 1929 to May 1931:

(1) IV. A Resurvey of the Ohio River Between Cincinnati, Ohio, and Louisville, Ky., including a Discussion of the Effects of Canalization and Changes in Sanitary Conditions Since 1914–16, by H. R. Crohurst (Public Health Bulletin No. 204, May 1933).

IV. Description of Ohio River Basin

15. *Geography.*—The Ohio River is formed by the confluence of the Allegheny and Monongahela Rivers at Pittsburgh, Pa. It flows 981 river-miles in a generally southwesterly direction and joins the Mississippi River at Cairo, Ill. The river bounds Ohio, Indiana, and Illinois (right bank); and West Virginia and Kentucky (left bank). Major tributaries, in addition to the Allegheny and Monongahela Rivers, are the Beaver, Muskingum, Hocking, Scioto, Little Miami, Miami, and Wabash Rivers (right bank); and the Little Kanawha, Kanawha, Guyandot, Big Sandy, Licking, Kentucky, Salt, Green, Cumberland, and Tennessee Rivers (left bank). Plate 1 is a general map of the Ohio River Basin.

16. The river drains an area of 203,900 square miles, which is second in size among the six major divisions of the Mississippi River watershed. Only the Missouri River Basin is larger. The longer axis of the basin extends from northeastern Mississippi to southwestern New York (800 miles), and the shorter axis from northern Georgia to northern Indiana (500 miles). The valley comprises 16 percent of the area of the Mississippi River Basin, almost 7 percent of the area of the United States, and portions of 14 States, namely: Alabama, Georgia, Illinois, Indiana, Kentucky, Maryland, Mississippi, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. Table 1 indicates the division of area by States and subbasins.

TABLE 1.—*Distribution of drainage area by States and subbasins, Ohio River Basin*

[Drainage area in square miles]

Basin	State														Total
	Alabama	Georgia	Illinois	Indiana	Kentucky	Maryland	Mississippi	New York	North Carolina	Ohio	Pennsylvania	Tennessee	Virginia	West Virginia	
Allegheny River								1,955			9,775				11,730
Monongahela River						430					2,770			4,180	7,380
Beaver River										1,360	1,785				3,145
Muskingum River										8,040					8,040
Little Kanawha River														2,320	2,320
Hocking River										1,185					1,185
Kanawha River									770				3,080	8,450	12,300
Guyandot River														1,670	1,670
Big Sandy River					2,280								1,015	985	4,280
Scioto River										6,510					6,510
Little Miami River										1,755					1,755
Licking River					3,670										3,670
Miami River				1,435						3,950					5,385
Kentucky River					6,940										6,940
Salt River					2,890										2,890
Green River					8,840							380			9,220
Wabash River			8,560	24,220						320					33,100
Cumberland River					7,025							10,975			18,000
Tennessee River	6,810	1,490			1,055		385		5,490			22,290	3,080		40,600
Ohio River (minor tributaries and direct drainage)			2,880	3,480	6,675					6,450	1,290			3,005	23,780
Total by States	6,810	1,490	11,440	29,135	39,375	430	385	1,955	6,260	29,570	15,620	33,645	7,175	20,610	203,900

17. *Topography.*—The Ohio River Basin lies in 4 major physiographic divisions, namely: The valley and ridge province, which borders the watershed on the east and is mountainous; the Appalachian Plateau, which lies to the west of the valley and ridge province; the interior low plateau, which lies south of the Ohio River and west of the Appalachian Plateau; and the central lowland, which includes virtually all of the basin north and west of the Ohio River below Portsmouth, Ohio, and which is a nearly level to undulating glaciated plain. The topography of the basin is diversified and is graduated between the mountains of the east and the low plateaus of the west.

18. *Geology.*—Broadly speaking, the Ohio River Basin is a region of but slightly disturbed Paleozoic sedimentary rocks that range in age from Cambrian to Permian. On the basis of general lithology and economic importance they are subject to two broad divisions: (1) The coal measures and, (2) a great series of calcareous sediments that extend from the base of the coal measures down through the Cambrian. The coal measures form the broad Appalachian plateaus of the eastern third of the basin in Pennsylvania, West Virginia, eastern Ohio, eastern Kentucky, eastern Tennessee, and northeastern Alabama and underlie the central lowlands of western Indiana, western Kentucky, and eastern Illinois. They consist of a great series of sandstones and shales containing many important coal beds. The calcareous rocks underlie a broad belt extending through the central portion of the basin in central Tennessee, central Kentucky, western Ohio, and eastern Indiana, where they have been brought above drainage by erosion on the crest of the Cincinnati anticline. The dominant rocks of this area are limestones and calcareous shales. The northern and western portions of the basin including nearly all of the drainage area on the north side of the Ohio River, below Portsmouth, Ohio, have been glaciated. In this area, bedrock is generally buried beneath thick deposits of glacial drift and many profound changes in the old preglacial drainage have taken place.

19. *Climate.*—The climate of the basin is temperate, and favors agriculture. Mean temperatures vary from 50° F. on the northern boundary to 60° F. on the southern boundary. Daily temperatures range from about −30° F. to over 100° F. The following tabulation shows mean air temperatures at several localities in the basin:

Location	Years of record	Mean air temperature, °F.												
		January	February	March	April	May	June	July	August	September	October	November	December	Average
Pittsburgh	67	30.7	32.3	39.6	51.2	62.4	70.7	74.6	72.9	66.4	55.7	43.2	34.2	51.8
Huntington	45	34.0	34.7	45.0	54.6	64.7	72.9	76.6	74.8	69.0	56.4	44.3	35.6	55.2
Cincinnati	71	30.3	32.8	40.9	52.4	63.1	71.2	75.1	73.6	67.1	55.7	42.5	33.4	53.1
Louisville	69	34.4	37.2	45.4	56.4	66.6	74.7	78.6	77.0	70.5	59.3	46.7	37.6	57.0
Nashville	71	38.6	41.6	49.2	59.0	68.2	75.6	79.1	77.8	71.8	61.0	49.0	41.0	59.3

20. *Hydrology.*—The mean annual precipitation in the valley varies from 51 inches in the extreme southwestern portion to 43 inches in the extreme northeastern portion, and from 60 inches in the extreme southeastern portion to 37 inches in the extreme northwestern portion. Storms have occurred with a precipitation of 6.5 inches in 48 hours,

over an area as large as 37,000 square miles. On the other hand, minimum monthly rainfalls of as low as 1.7 inches have persisted for 6 months at a time over a considerable portion of the basin. In general, rainfall and run-off are high in the late winter and in the spring, and are low in the summer.

21. The following tabulation shows flow data for several Ohio River stations for the period 1930 to 1941, inclusive:

Item	Pittsburgh [1]	Louisville [1]	Paducah [1]
Minimum monthly average flow	1,300	4,400	23,000
Median of minimum monthly average flows	4,900	14,800	42,400
Mean of minimum monthly average flows	4,900	14,900	47,100
Maximum flow	557,000	1,110,000	[2] 1,850,000
Median of maximum monthly average flows	71,000	292,000	648,000
Mean of maximum monthly average flows	83,700	316,800	669,700
Median of monthly average flows	20,000	67,800	147,000
Mean flow	28,000	104,400	231,400
Difference between stage of extreme high and extreme low water, feet	[3] 37.6	[4] 50.7	[5] 53.1
Ratio of maximum flow to minimum monthly average flow	428:1	252:1	80:1

[1] Cubic feet per second.
[2] Includes 70,000 cubic feet per second flow in Bay Creek-Cache River back channel.
[3] Minimum stage measured prior to raising of Emsworth Dam during years 1935-38.
[4] Upper pool. Low stages affected by dam No. 41.
[5] Low stages affected by dam No. 52.

22. *Population.*—The population of the basin approximates 18,816,000 and comprises over 14 percent of that of the United States. Population densities are as follows:

	Persons per square mile
Entire basin	92
Area above Wheeling, W. Va	190
Area below Wheeling, W. Va	80

Almost half of the population is urban, and urban development includes metropolitan centers such as Pittsburgh, Cincinnati, and Louisville.

23. Basin populations are shown in the following tabulation for the period 1890 to 1940, inclusive:

Year	Population					
	Rural		Urban		Total	
	Number	Percent increase over preceding period	Number	Percent increase over preceding period	Number	Percent increase over preceding period
1890	8,306,000		2,723,000		11,029,000	
1900	8,994,000	8	3,761,000	38	12,755,000	16
1910	9,272,000	3	5,110,000	36	14,382,000	13
1920	9,429,000	2	6,469,000	27	15,898,000	11
1930	9,681,000	3	7,852,000	21	17,533,000	10
1940	10,602,000	10	8,214,000	5	18,816,000	7

Table 2 indicates the distribution of population by States and subbasins.

TABLE 2.—*Distribution of population by States and subbasins, Ohio River Basin*

Basin	Class	Population, 1940 census [1]														
		State														Total by basins
		Alabama	Georgia	Illinois	Indiana	Kentucky	Maryland	Mississippi	New York	North Carolina	Ohio	Pennsylvania	Tennessee	Virginia	West Virginia	
Allegheny River	Rural								73, 044			640, 104				713, 148
	Urban								76, 377			447, 169				523, 546
	Total								149, 421			1, 087, 273				1, 236, 694
Monongahela River	Rural						14, 646					423, 869			241, 028	679, 543
	Urban						0					477, 977			107, 154	585, 131
	Total						14, 646					901, 846			348, 182	1, 264, 674
Beaver River	Rural										110, 977	140, 124				251, 101
	Urban										307, 000	170, 267				477, 267
	Total										417, 977	310, 391				728, 368
Muskingum River	Rural										413, 578					413, 578
	Urban										398, 450					398, 450
	Total										812, 028					812, 028
Little Kanawha River	Rural														92, 355	92, 355
	Urban														0	0
	Total														92, 355	92, 355
Hocking River	Rural										65, 422					65, 422
	Urban										48, 133					48, 133
	Total										113, 555					113, 555
Kanawha River	Rural									35, 713				123, 455	500, 159	659, 327
	Urban									0				30, 174	145, 344	175, 518
	Total									35, 713				153, 629	645, 503	834, 845

[1] Urban population includes incorporated places each having a population of 2,500 or more.

TABLE 2.—*Distribution of population by States and subbasins, Ohio River Basin*—Continued

Basin	Class	Population, 1940 census [1]														
		State														Total by basins
		Alabama	Georgia	Illinois	Indiana	Kentucky	Maryland	Mississippi	New York	North Carolina	Ohio	Pennsylvania	Tennessee	Virginia	West Virginia	
Guyandot River	Rural														140, 065	140, 065
	Urban														8, 192	8, 192
	Total														148, 257	148, 257
Big Sandy River	Rural					198, 835								66, 711	115, 174	380, 720
	Urban					13, 613								0	17, 572	31, 185
	Total					212, 448								66, 711	132, 746	411, 905
Scioto River	Rural										291, 761					291, 761
	Urban										447, 790					447, 790
	Total										739, 551					739, 551
Little Miami River	Rural										111, 470					111, 470
	Urban										24, 004					24, 004
	Total										135, 474					135, 474
Licking River	Rural					145, 230										145, 230
	Urban					24, 913										24, 913
	Total					170, 143										170, 143
Miami River	Rural				59, 367						269, 010					328, 377
	Urban				48, 045						454, 059					502, 104
	Total				107, 412						723, 069					830, 481
Kentucky River	Rural					385, 916										385, 916
	Urban					96, 053										96, 053
	Total					481, 969										481, 969
Salt River	Rural					123, 865										123, 865
	Urban					16, 003										16, 003
	Total					139, 868										139, 868

Green River	Rural					367,117							32,877			399,994
	Urban					44,398							0			44,398
	Total					411,515							32,877			444,392
Wabash River	Rural			276,198	1,020,389						13,881					1,310,468
	Urban			170,618	1,022,671						4,841					1,198,130
	Total			446,816	2,043,060						18.722					2,508.598
Cumberland River	Rural					371,398							479,880			851,278
	Urban					56,090							221,634			277,724
	Total					427,488							701,514			1,129,002
Tennessee River	Rural	310,585	61,371			43,665		15,055		251.230			974,450	203,001		1,859.357
	Urban	79,464	3,538			3,773		0		67,729			445.337	32,100		631,941
	Total	390,049	64,909			47,438		15.055		318,959			1,419.787	235,101		2,491,298
Ohio River (minor tributaries and direct drainage).	Rural			109,984	181,627	317,230					380,314	221,648			187,965	1,398,768
	Urban			43,658	171,351	582,657					785,904	897,447			222,604	2,703,621
	Total			153,642	352,978	899,887					1.166,218	1,119,095			410,569	4,102,389
Total by States	Rural	310,585	61,371	386,182	1,261,383	1,953,256	14,646	15,055	73,044	286.943	1,656,413	1,425,745	1,487,207	396,167	1,276,746	10,601,743
	Urban	79,464	3,538	214,276	1,242,067	837,500	0	0	76,377	67,729	2,470,181	1,992,860	666,971	62,274	500,866	8.214,103
	Total	390,049	64,909	600,458	2,503,450	2,790,756	14,646	15,055	149,421	354,672	4,126,594	3,418,605	2,154,178	455,441	1,777,612	18,815.846

[1] Urban population includes incorporated places each having a population of 2,500 or more.

24. *Industry.*—Portions of the Ohio River basin are highly industrialized, and agriculture, mining, and manufacturing are extensive. Principal natural and manufactured products include coal; limestone; sandstone; gravel; natural gasoline; petroleum; natural gas; salt; ores of iron, zinc, aluminum, and manganese; products of iron and steel plants, rolling mills, blast furnaces, foundries, and machine shops; motor vehicles, parts, and accessories; rubber goods; railroad equipment; electrical machinery; knit goods; furniture; electric power; lumber; cement; chemicals; farm products; and others of value.

25. *River uses.*—The streams of the Ohio River system are extensively used for many purposes, including the following:

(*a*) Public water supply.
(*b*) Industrial water supply.
(*c*) Agricultural water supply.
(*d*) Waste disposal.
(*e*) Support of plant and animal life.
(*f*) Recreation.
(*g*) Navigation.
(*h*) Hydroelectric power production.

V. Survey (Character and Extent)

26. The conduct of the survey was divided into four main sections, as follows:

(*a*) Field surveys, in which the source, type, volume, and strength of pollutants were determined, and by means of which information concerning present water usage, waste-disposal methods, and similar data were obtained.

(*b*) Laboratory surveys, in which various physical, chemical, biological, and sanitary characteristics of the involved streams were determined and were related to pollution sources and variations in season and stream flow.

(*c*) Hydrometric surveys, in which determinations of discharge volumes and stream velocities were made for correlation with field and laboratory results.

(*d*) Reservoir and reservoir site surveys, to determine water storage which may be made available for increasing low-water flows in order to further dilute polluting substances.

27. *Field surveys.*—Data on the source, type, volume, and strength of pollutants were obtained by 11 field stations maintained in the offices of State health departments, and the Tennessee Valley Authority. Sanitary surveys were made of some 3,700 municipalities and 1,800 industrial establishments. A twelfth field unit was assigned to the study of acid mine drainage problems.

28. Studies of specific industrial waste problems were made in cooperation with the cities of Cincinnati and Louisville, the State of West Virginia, and the Tennessee Valley Authority.

29. Correlated work included the preparation of industrial waste guides which outline industrial processes, quantities and strengths of industrial wastes, and waste treatment and recovery practices and their effectiveness; studies of pollution abatement legislation and administration; studies of the cost of construction and operation of waste treatment plants; and other investigations.

30. *Laboratory studies.*—The major accomplishment of the laboratory studies was the determination of the physical, bacterial, and

chemical characteristics of water samples collected from some 2,000 stream stations in the Ohio River Basin. More than 71,000 water samples were examined.

31. A base laboratory was located at Cincinnati, Ohio, and field laboratories included the quarterboat *Kiski* and six mobile laboratories in automobile trailers.

32. Analytical practice conformed to the latest standard methods of the American Public Health Association and the American Water Works Association. Technique in the base and field laboratories was carefully standardized. Table 3 outlines the routine laboratory examinations made, and indicates their significance.

TABLE 3.—*Significance of various physical, chemical, and bacteriological tests used in Ohio River pollution survey*

Test	Explanation
	PHYSICAL AND CHEMICAL TESTS
Temperature	Governs the solubility of oxygen and influences rates of purification.
Turbidity	An index of the density of silt or other suspended matter carried by the stream
pH	Or hydrogen-ion concentration, indicates the relative acidity or alkalinity of a water.
Alkalinity	Represents the content of carbonates, bicarbonates, hydroxides, and occasionally borates, silicates, and phosphates.
Total and volatile suspended matter.[1]	Represents the concentration of suspended matter, in terms of dry solids, and is a rough index of the organic waste material present.
Dissolved oxygen	Essential to natural purification of streams and the maintenance of aquatic life, is drawn upon to support biochemical oxidation of organic waste and is replaced by absorption from the atmosphere and the photosynthetic action of some water plants including algae. A deficiency in dissolved oxygen below the saturation level indicates the presence of polluting organic substances which are absorbing oxygen from the stream water. The degree of this deficiency is a measure of the deoxygenating effect of the polluting matter and hence an index of the degree of pollution in a particular stream zone.
5-day biochemical oxygen demand at 20° C. (B. O. D.).	Indicates the amount of dissolved oxygen which may be expected to be absorbed from the stream water in 5 days at 20° C. to support the biochemical oxidation of the organic pollution carried by the stream at the point of sampling.
	BACTERIOLOGICAL TESTS
Total count on agar in 24 hours at 37° C.[1]	Considered in conjunction with the coliform bacteria the plate count is of value both as an indication of pollution and as a rough measure of natural stream purification.
Coliform bacteria (determined by standard fermentation tube test at 37° C.).	Expressed as "most probable number" (M. P. N.). This test is the most delicate and specific test for pollution by sewage as it shows the approximate density of a group of bacteria which are always present in large numbers in sewage and are relatively few in number in other stream pollutants. Coliform bacteria are normal inhabitants of the intestines of warm-blooded animals and are discharged in large numbers in human feces, which constitute the principal source of these bacteria in sewage.
Coliform bacteria (determined by direct plate count on brilliant green lactose bile at 37° C.).	Utilizes the plate count method, rather than the fermentation tube method, for the determination of coliform bacteria using a culture medium selective for this type of organism.

[1] Discontinued as a routine test at the end of 1939.

33. In general, sampling stations were chosen above and below pollution sources, in order to measure effects at individual localities. Less frequently, sampling stations were located at several points, progressively distant from upstream pollution. Because of this, polluted samples generally were indicative of water quality at the head of polluted reaches which is usually poorer than the average quality of the reaches.

34. In addition to the routine stream sampling program, a number of special investigations were made, including a study of water quality requirements for various uses; an epidemiological study of the occurrence of intestinal diseases suspected of being water borne; biological studies of the effect of pollution on plankton and higher forms of

aquatic life; a controlled study to determine the effects of mine sealing on stream quality; taste and odor studies; and others.

35. *Hydrometric surveys.*—Collection and analysis of hydrometric data were essential to permit interpretation of field and laboratory studies. Determination of stream velocities, discharge volumes, and minimum-flow conditions were required to establish a quantitative measure of the pollution of streams involved, as well as to establish practical limits of waste carrying and self-purification capacity. These data were developed by field observations concurrent with water sampling operations, establishment of key observation stations on major streams, utilization of existing stream measurement facilities, and examination of the literature on the subject, with particular reference to low-flow conditions.

36. *Reservoir and reservoir-site surveys.*—All existing reservoirs were examined to determine whether they provide or can be modified to provide sufficient storage for increasing low-water flows for dilution of polluted water. Plans for proposed reservoirs were also examined to determine the advisability of including therein provisions for increasing such low-water flows. Attendant investigations revealed that reservoirs, for the sole purpose of increasing low-water flows for the dilution of pollution, are not warranted.

37. *Interpretation of survey results.*—Stream conditions are reported as found at the time of actual physical survey and sampling. The period of time devoted to the study of the specific locations was necessarily limited so that the results of the survey seldom indicate the true sanitary condition of the streams under the most adverse condition. For example, the survey indicated very satisfactory and desirable stream conditions in the Kanawha River at its junction with the Ohio River. Here the effects of pollution from the Charleston, W. Va., area appear negligible. However, it is known that in 1930 rains following a drought in the Kanawha Basin washed sludge from the river bottom into the Ohio River. This apparently resulted in spreading a disease, originating in Charleston, W. Va., and known as gastroenteritis, far down the Ohio River. It should be kept in mind, therefore, that in interpreting the facts as presented, reservations should be made because extremely adverse conditions which occur infrequently could not be included in the report.

VI. Existing Conditions and Damages

A. SOURCES OF POLLUTION

38. *Nature of pollutants.*—Wastes from sewered communities, industrial wastes of primarily local significance, and industrial wastes, including acid mine drainage, having a widespread effect, were determined to be the important pollutants being discharged to the streams of the Ohio River Basin.

39. The polluting strengths of these wastes, despite all corrective efforts to date, are as follows:

Sewered domestic wastes (population equivalent based on biochemical oxygen demand)	6, 396, 400
Industrial wastes (population equivalent based on biochemical oxygen demand)	9, 071, 700
Total organic wastes (population equivalent based on biochemical oxygen demand)	15, 468, 100
Acid wastes (as tons per year of calcium carbonate)	1, 864, 800

40. In this report the polluting strengths of organic industrial wastes and domestic treatment plant residuals are expressed in terms of population equivalent, obtained by comparing the biochemical oxygen demand of the wastes with the unit biochemical oxygen demand of untreated human sewage, which, as shown by extensive observation of 5-day biochemical oxygen demand at 20° C., averages 0.168 pound of oxygen per capita per day.

41. *Domestic wastes.*—The total population of the basin was 18,816,000 in 1940. Of this number, 8,214,100 were urban dwellers in 529 incorporated communities having 2,500 or more inhabitants. Domestic wastes from 8,561,200 persons in sewered areas, largely urban, have caused objectionable concentrations in excess of the waste assimilating capacities of the waterways. There are 1,681 domestic waste sources where 100 or more persons are sewered. The communities in the latter group are distributed as follows:

Sewered communities with 100 or more persons connected to sewers

Basin	Number	Basin	Number
Allegheny River	167	Miami River	60
Monongahela River	172	Kentucky River	25
Beaver River	54	Salt River	15
Muskingum River	78	Green River	26
Little Kanawha River	9	Wabash River	268
Hocking River	19	Cumberland River	55
Kanawha River	116	Tennessee River	172
Guyandot River	37	Minor tributaries	114
Big Sandy River	69	Ohio River direct	136
Scioto River	52		
Little Miami River	22	Total	1,681
Licking River	15		

The population now served by water supplies but not sewered is 1,805,400. Any increase in domestic sewage loadings from this source will occur mainly in communities of from 250 to 2,500 inhabitants, of which there are over 1,600 in the basin.

42. Human and animal wastes originating in rural areas are of comparatively minor significance because they are well distributed and usually not deposited directly into streams.

43. Sewage treatment facilities at 464 locations serve 2,913,300 persons and are estimated to reduce the population equivalent of all sewered domestic wastes from 8,561,200 persons to 6,396,400. About $70,190,000 have been expended on sewage treatment plants, including the cost of interceptor sewer construction. Plants generally have been built at communities on smaller streams where raw sewage dumping constitutes a major local nuisance. On the Ohio River and its larger tributaries sewage treatment plants are notably lacking apparently due to financial and administrative difficulties as well as to the fact that large natural stream flows sweep the wastes downstream, thereby preventing a grossly objectionable local nuisance. Communities which suffer because of upstream neighbors cannot, of course, solve their own problems completely.

44. Pertinent data with respect to domestic waste loadings are summarized in table 4.

TABLE 4.—*Distribution of domestic wastes by States and subbasins, Ohio River Basin*

Basin and State	Drainage area, square miles	Population, 1940 census			Population served by sewers	Existing sewage treatment plants						Capital cost of existing sewage treatment plants and interceptors	Domestic sewage as discharged, population equivalent, based on biochemical oxygen demand		
		Rural	Urban	Total		Primary		Secondary		Total			Residual from existing treatment plants	Untreated sewered wastes	Total
						Number	Population served	Number	Population served	Number	Population served				
Allegheny River	11,730	713,148	523,546	1,236,694	919,800	22	109,000	19	55,300	41	164,300	$5,460,000	82,500	755,500	838,000
Monongahela River	7,380	679,543	585,131	1,264,674	862,200	13	45,800	7	20,300	20	66,100	1,500,000	33,100	796,100	829,200
Beaver River	3,145	251,101	477,267	728,368	515,700	17	134,300	18	84,100	35	218,400	4,760,000	102,700	297,300	400,000
Muskingum River	8,040	413,578	398,450	812,028	422,600	13	78,700	18	206,900	31	285,600	4,550,000	68,800	137,000	205,800
Little Kanawha River	2,320	92,355	0	92,355	10,200	1	1,400	1	3,400	2	4,800	190,000	1,400	5,400	6,800
Hocking River	1,185	65,422	48,133	113,555	48,400	2	1,300	2	22,700	4	24,000	840,000	4,200	24,400	28,600
Kanawha River	12,300	659,327	175,518	834,845	226,500	6	20,900	6	28,600	12	49,500	1,300,000	18,100	177,000	195,100
Guyandot River	1,670	140,065	8,192	148,257	23,900	0	0	0	0	0	0	0	0	23,900	23,900
Big Sandy River	4,280	380,720	31,185	411,905	55,000	0	0	3	2,600	3	2,600	70,000	500	52,400	52,900
Scioto River	6,510	291,761	447,790	739,551	412,600	15	43,900	18	357,600	33	401,500	12,890,000	62,800	11,100	73,900
Little Miami River	1,755	111,470	24,004	135,474	109,700	3	8,100	8	16,500	11	24,600	530,000	4,700	85,100	89,800
Licking River	3,670	145,230	24,913	[1] 170,143	25,200	0	0	2	11,200	2	11,200	290,000	1,600	14,000	15,600
Miami River	5,385	328,377	502,104	830,481	550,500	10	89,000	21	333,400	31	422,400	9,380,000	88,700	128,100	216,800
Kentucky River	6,940	385,916	96,053	481,969	105,300	3	1,200	10	68,200	13	69,400	1,370,000	11,100	35,900	47,000
Salt River	2,890	123,865	16,003	139,868	20,300	1	1,700	7	15,400	8	17,100	670,000	3,600	3,200	6,800
Green River	9,220	399,994	44,398	444,392	45,000	8	29,300	3	5,000	11	34,300	450,000	20,100	10,700	30,800
Wabash River	33,100	1,310,468	1,198,130	2,508,598	1,119,700	10	39,100	74	782,900	84	822,000	16,650,000	164,100	297,700	461,800
Cumberland River	18,000	851,278	277,724	1,129,002	237,300	7	9,300	10	55,000	17	64,300	1,660,000	14,100	173,000	187,100
Tennessee River	40,600	1,859,357	631,941	2,491,298	591,300	26	41,800	18	56,600	44	98,400	2,750,000	36,700	492,900	529,600
Minor tributary basins	23,780	1,254,858	130,344	1,385,202	167,800	12	13,900	30	96,400	42	110,300	3,800,000	23,000	57,500	80,500
Ohio River (direct drainage)		143,910	2,573,277	2,717,187	2,092,200	4	6,100	16	16,400	20	22,500	1,080,000	6,700	2,069,700	2,076,400
Total	203,900	10,601,743	8,214,103	18,815,846	8,561,200	173	674,800	291	2,238,500	464	2,913,300	70,190,000	748,500	5,647,900	6,396,400
Alabama	6,810	310,585	79,464	390,049	63,000	2	4,400	0	0	2	4,400	140,000	2,800	58,600	61,400
Georgia	1,490	61,371	3,538	64,909	7,900	2	2,100	1	3,500	3	5,600	150,000	1,800	2,300	4,100
Illinois	11,440	386,182	214,276	600,458	203,400	3	29,800	23	120,500	26	150,300	3,760,000	23,600	53,100	76,700
Indiana	29,135	1,261,383	1,242,067	2,503,450	1,164,200	9	10,500	68	713,900	77	724,400	14,990,000	144,500	439,800	584,300
Kentucky	39,375	1,953,256	837,500	2,790,756	849,000	22	49,200	42	149,400	64	198,600	4,585,000	54,300	650,400	704,700
Maryland	430	14,646	0	14,646	3,000	0	0	0	0	0	0	0	0	3,000	3,000
Mississippi	385	15,055	0	15,055	700	0	0	0	0	0	0	0	0	700	700
New York	1,955	73,044	76,377	149,421	110,500	9	79,500	2	1,500	11	81,000	4,260,000	51,000	29,500	80,500
North Carolina	6,260	286,943	67,729	354,672	103,000	3	1,500	10	3,500	13	5,000	210,000	1,500	98,000	99,500

Ohio	29, 570	1, 656, 413	2, 470, 181	4, 126, 594	2, 593, 800	55	239, 000	82	975, 500	137	1, 214, 500	30, 380, 000	250, 500	1, 379, 300	1, 629, 800
Pennsylvania	15, 620	1, 425, 745	1, 992, 860	3, 418, 605	2, 186, 800	36	200, 300	38	159, 400	74	359, 700	6, 940, 000	162, 600	1, 827, 100	1, 989, 700
Tennessee	33, 645	1, 487, 207	666, 971	2, 154, 178	553, 600	19	24, 000	14	76, 700	33	100, 700	2, 900, 000	28, 400	452, 900	481, 300
Virginia	7, 175	393, 167	62, 274	455, 441	58, 600	2	8, 600	3	5, 900	5	14, 500	380, 000	7, 900	44, 100	52, 000
West Virginia	20, 610	1, 276, 746	500, 866	1, 777, 612	663, 700	11	25, 900	8	28, 700	19	54, 600	1, 495, 000	19, 600	609, 100	628, 700
Total	203, 900	10, 601, 743	8, 214, 103	18, 815, 846	8, 561, 200	173	674, 800	291	2, 238, 500	464	2, 913, 300	70, 190, 000	748, 500	5, 647, 900	6, 396, 400

[1] Population of Covington-Newport area is included under "Ohio River (direct drainage)."

45. *Industrial wastes.*—Industrial wastes may have local or wide effects on streams, depending upon the nature of the waste and the amount of dilution available. Many streams are seriously and extensively damaged by industrial pollution. Acid wastes from coal mines and metallurgical industries are of importance over a considerable water distance, as are some wastes such as phenols, which produce tastes in water supplies.

46. The aggregate organic waste load discharged from industrial establishments has a human population equivalent of 9,974,300, despite corrective measures now applied by some industries. Ninety percent of this load, from 1,604 significant sources, is discharged directly to streams. The remainder receives treatment in domestic sewage treatment plants. The total residual population equivalent of all industrial wastes, as now discharged to streams, is estimated to be 9,071,700.

47. Much of the industrial wastes served by municipal treatment and over 30 percent of those not served are from food processing and allied industries. In general, these are well distributed throughout the area, although a majority of the cannery wastes is discharged in the Wabash River Basin, and a majority of the distillery wastes is discharged in the Kentucky and Salt River Basins and in the Louisville area on the Ohio River. The rapidly expanding chemical industry contributes 21 percent of the industrial waste population equivalent not served by municipal treatment. This is largely in the Kanawha and Tennessee River Basins. An increase in the quantity and extent of wastes of this type may be expected. Paper and strawboard plants contribute over 15 percent of the industrial waste population equivalent, the largest sources of these wastes being located in the Allegheny, Wabash, and Tennessee River Basins. The effects of this pollutant should be lessened as improved treatment methods are developed.

48. Pertinent data with respect to industrial waste loadings are summarized in table 5.

TABLE 5.—*Distribution of industrial wastes by States and subbasins, Ohio River Basin*

Basin and State	Drainage area, square miles	Industrial wastes connected to municipal treatment-population equivalent (biochemical oxygen demand)		Industrial wastes not connected to municipal treatment as discharged from industrial establishments [1]																				
				Brewing			Byproduct coke			Canning			Chemical			Distilling			Meat			Milk		
		Prior to municipal treatment	As discharged	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)
Allegheny River	11,730	5,200	3,200	7	5	53,800	2	2	84,000	3	2	57,900	7	6	9,600	3	3	19,600	15	11	90,600	44	13	17,900
Monongahela River	7,380	2,000	1,200	5		49,100	3	2	240,000				3			3	2	94,000	6	4	6,100	5	2	3,300
Beaver River	3,145	11,800	5,800	2	2	5,300	4	3	80,400				4	2					2	2	7,200	3	2	3,400
Muskingum River	8,040	40,100	5,900	3	3	7,100	2	2	14,200										8	7	17,500	28	24	6,300
Little Kanawha River	2,320																							
Hocking River	1,185	1,400	200																2	2	5,800	2	2	1,400
Kanawha River	12,300	11,100	900							2	1	1,600	11	4	1,378,000									
Guyandot River	1,670																							
Big Sandy River	4,280																							
Scioto River	6,510	348,600	100,200							11	9	32,200	4	3					8	5	2,700	7	4	700
Little Miami River	1,755	2,800	1,400							8	4	6,900												
Licking River	3,670																		2	2	400	2	2	300
Miami River	5,385	166,200	30,600	3		1,700				14	6	26,800							6	2	3,200	14	3	1,500
Kentucky River	6,940	32,900	4,900							3	2	6,300				9	9	86,200	6	2	1,100	3	1	1,000
Salt River	2,890	700	300													24	24	97,500				2	2	700
Green River	9,220	1,400	600																3	3	1,800	2	2	400
Wabash River	33,100	547,500	132,600	3	3	42,000				123	121	530,000				2	2	121,000	31	30	36,100	45	34	11,900
Cumberland River	18,000	17,900	3,000							7	4	2,100	2		72,000				5	3	37,500	25	9	9,600
Tennessee River	40,600	5,400	2,400							24	2	38,400	21	11	353,200				19	2	40,200	25	2	9,500
Ohio River, minor tributaries and direct	23,780	900	100	13	13	103,200	8	7	234,000	20	7	55,800	10	7	67,300	24	11	588,700	59	39	134,900	43	3	17,200
Total	203,900	1,195,900	293,300	38	27	264,300	23	17	745,200	218	160	758,900	65	36	1,880,400	67	53	1,009,700	173	115	385,700	253	107	85,100

See footnote at end of table.

TABLE 5.—*Distribution of industrial wastes by States and subbasins, Ohio River Basin*—Continued

Basin and State	Drainage area, square miles	Industrial wastes connected to municipal treatment-population equivalent (biochemical oxygen demand): Prior to municipal treatment	Industrial wastes connected to municipal treatment-population equivalent (biochemical oxygen demand): As discharged	Industrial wastes not connected to municipal treatment as discharged from industrial establishments [1] — Brewing: Number	Brewing: At least minor corrections applied	Brewing: Population equivalent (biochemical oxygen demand)	Byproduct coke: Number	Byproduct coke: At least minor corrections applied	Byproduct coke: Population equivalent (biochemical oxygen demand)	Canning: Number	Canning: At least minor corrections applied	Canning: Population equivalent (biochemical oxygen demand)	Chemical: Number	Chemical: At least minor corrections applied	Chemical: Population equivalent (biochemical oxygen demand)	Distilling: Number	Distilling: At least minor corrections applied	Distilling: Population equivalent (biochemical oxygen demand)	Meat: Number	Meat: At least minor corrections applied	Meat: Population equivalent (biochemical oxygen demand)	Milk: Number	Milk: At least minor corrections applied	Milk: Population equivalent (biochemical oxygen demand)
Alabama	6,810	300	200	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	3	----	4,800	----	----	----
Georgia	1,490	0	0	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Illinois	11,440	10,100	4,100	----	----	----	----	----	----	7	7	800	----	----	----	----	----	----	5	5	500	3	3	300
Indiana	29,135	516,900	129,900	5	5	83,000	----	----	----	125	118	554,800	----	----	----	6	6	193,500	42	37	92,500	44	31	11,900
Kentucky	39,375	49,700	8,100	7	4	43,900	----	----	----	11	2	34,500	----	----	----	53	40	699,900	43	25	65,600	40	9	17,500
Maryland	430	0	0	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Mississippi	385	0	0	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
New York	1,955	5,200	3,200	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	15	8	3,800
North Carolina	6,260	100	100	----	----	----	----	----	----	6	----	3,700	----	----	----	----	----	----	2	----	3,300	3	1	900
Ohio	29,570	580,500	137,000	9	6	15,900	8	7	125,600	34	20	67,400	8	6	300	----	----	----	30	22	40,200	57	37	14,500
Pennsylvania	15,620	13,800	7,000	14	7	117,900	7	5	454,000	4	2	56,700	14	7	9,600	6	5	113,600	21	15	97,900	33	6	17,100
Tennessee	33,645	8,200	2,800	----	----	----	----	----	----	26	6	37,700	20	9	375,700	----	----	----	16	3	68,100	46	10	17,800
Virginia	7,175	0	0	----	----	----	----	----	----	----	----	----	3	2	----	----	----	----	----	----	----	----	----	----
West Virginia	20,610	11,100	900	----	----	----	4	4	125,000	----	----	----	18	10	1,440,500	----	----	----	10	8	12,100	11	2	1,300
Total	203,900	1,195,900	293,300	38	27	264,300	23	17	754,200	218	160	758,900	65	36	1,880,400	67	53	1,009,700	173	115	385,700	253	107	85,100

Basin and State	Industrial wastes not connected to municipal treatment as discharged from industrial establishments[1]																					Industrial wastes as discharged—total population equivalent (biochemical oxygen demand)	
	Oil refining			Paper			Steel			Tanning			Textile			Miscellaneous			Total				
	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	From industrial establishments[2]	To streams[3]
Allegheny River	25	23	35,900	3	2	94,400	27	11		11	6	63,700	8	4	124,300	41	5	21,500	196	93	673,200	678,400	676,400
Monongahela River							26	12		2	2	25,000	2		1,000	31	2	5,800	86	26	424,300	426,300	425,500
Beaver River							39	24								22	10	56,300	76	45	152,600	164,400	158,400
Muskingum River	2	2	11,400	4	2	210,000	11	5								26	11	14,000	84	56	280,500	320,600	286,400
Little Kanawha River																							
Hocking River																2	2	200	4	4	7,200	8,600	7,400
Kanawha River	2	2	3,600							3	3	18,700	9	2	8,300	36	17	68,700	65	31	1,479,100	1,490,200	1,480,000
Guyandot River																1	1	200	1	1	200	200	200
Big Sandy River																1	1	400	1	1	400	400	400
Scioto River				3	3	39,200										[4] 15	[4] 9	2,500	[4] 48	[4] 33	77,300	425,900	177,500
Little Miami River																		[5] 51,000	8	4	[5] 57,900	60,700	59,300
Licking River																3	1	2,600	7	5	3,300	3,300	3,300
Miami River				21	17	167,000										[6] 31	[6] 12	35,100	[6] 89	[6] 40	235,300	401,500	265,900
Kentucky River																2	1	3,900	23	15	98,500	131,400	103,400
Salt River																1	1		27	27	98,200	98,900	98,500
Green River																1		200	6	5	2,400	3,800	3,000
Wabash River	2	2	17,000	12	11	444,300	4	2					3		8,200	25	12	14,000	250	217	1,224,500	1,772,000	1,357,100
Cumberland River	3	3	1,200										8		9,000	18	4	109,200	68	23	240,600	258,500	243,600
Tennessee River				9	8	584,400	1			9	2	79,900	80	1	138,700	38	13	56,300	227	41	1,300,600	1,306,000	1,303,000
Ohio River, minor tributaries and direct	12	11	46,100	6	3	19,900	66	17		3		21,600	10	3	44,400	64	20	[7] 1,089,200	338	141	[7] 2,422,300	2,423,200	2,422,400
Total	47	44	116,500	59	46	1,659,200	173	71		32	13	269,600	122	10	335,100	333	109	1,268,700	1,604	808	8,778,400	9,974,300	9,071,700

See footnote at end of table.

Basin and State	Industrial wastes not connected to municipal treatment as discharged from industrial establishments [1]																					Industrial wastes as discharged—total population equivalent (biochemical oxygen demand)	
	Oil refining			Paper			Steel			Tanning			Textile			Miscellaneous			Total				
	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	Number	At least minor corrections applied	Population equivalent (biochemical oxygen demand)	From industrial establishments [2]	To streams [3]
Alabama													3		1, 600	10	1	2, 700	16	1	9, 100	9, 400	9, 300
Georgia													7	1	57, 000				7	1	57, 000	57, 000	57, 000
Illinois	2	2	17, 000													11	9	61, 000	28	26	79, 600	89, 700	83, 700
Indiana	3	2	2, 600	12	11	385, 600	4	2		2	1	12, 000	3		8, 200	40	16	32, 700	286	229	1, 376, 800	1, 893, 700	1, 506, 700
Kentucky	6	6	32, 800				2	1					7		1, 700	30	14	80, 100	199	101	976, 000	1, 025, 700	984, 100
Maryland																							
Mississippi																							
New York	2	2	2, 500										3	2	50, 900	16	7	14, 700	36	19	71, 900	77, 100	75, 100
North Carolina				3	3	381, 400				5	2	45, 400	13		20, 400	5		54, 400	37	6	509, 500	509, 600	509, 600
Ohio	2	2	11, 400	30	24	434, 900	43	20		2		57, 000	2	1	2, 500	81	33	1, 152, 400	306	178	1, 922, 100	2, 502, 600	2, 059, 100
Pennsylvania	27	25	43, 900	3	2	94, 400	103	45		10	5	57, 100	5	2	73, 400	74	7	20, 600	321	133	1, 156, 200	1, 170, 000	1, 163, 200
Tennessee	2	2	1, 000	5	5	188, 100				4		34, 500	58		66, 200	38	16	156, 700	215	51	945, 800	954, 000	948, 600
Virginia													12	2	10, 200	11	6	25, 300	26	10	35, 500	35, 500	35, 500
West Virginia	3	3	5, 300	3		900	21	3		4	4	37, 000	5		15, 100	48	19	1, 700	127	53	1, 638, 900	1, 650, 000	1, 639, 800
Total	47	44	116, 500	59	46	1, 659, 200	174	71	----	32	13	269, 600	122	10	335, 100	333	109	1, 268, 700	1, 604	808	8, 778, 400	9, 974, 300	9, 071, 700

[1] Single industries in a specific classification in any basin or State are included in the "Miscellaneous" classification when listed by individual basins and States, and in the proper specific classification when listed in the "Total" columns.

[2] Does not include the effect of municipal treatment which is now applied to a portion of the total industrial waste load.

[3] Includes the effect of municipal treatment which is now applied to a portion of the total industrial waste load.

[4] Includes 7 metal plants, 4 applying some corrective measures, population equivalent of wastes neglibible.

[5] Industrial waste population equivalent of 51,000 to Cincinnati sewers, number of industries not listed.

[6] Includes 19 metal plants, 8 applying some corrective measures, population equivalent of wastes negligible.

[7] Industrial waste population equivalent of 1,057,400 to Cincinnati sewers, number of industries not listed.

49. *Acid wastes.*—Acid coal-mine drainage is an inorganic industrial waste common to all portions of the Ohio River Basin which lie within the bituminous coal fields. It seriously damages streams ranging from small runs to major tributaries. Acid wastes of lesser importance originate primarily in spent pickle liquor discharged by the metallurgical industries. The total acid load discharged to streams, despite corrective efforts to date, is 1,864,800 tons per year (calcium carbonate equivalent). Ninety-eight percent is from coal mines. The heaviest concentrations of acid wastes are in the Monongahela and lower Allegheny River Basins. Acid loads have increased in proportion to the cumulative tonnage of coal mined, and severe stream pollution by mine drainage is a comparatively recent problem. Continued coal production will result in increasingly large acid loads. Since less than 5 percent of the coal resources of the Ohio River Basin has been mined, acid pollution may continue to become more severe indefinitely, unless corrective steps are taken.

50. Pertinent data with respect to acid waste loadings are summarized in table 6.

TABLE 6.—*Distribution of acid wastes by States and subbasins—Ohio River Basin*

Basin and State	Drainage area (square miles)	Mine acid load—tons per year ($CaCO_3$ equivalent)						Pickle liquor free acid load, tons per year ($CaCO_3$ equivalent)	Total residual acid load, tons per year ($CaCO_3$ equivalent)
		Prior to sealing program (by status of mines)				Removed by mine sealing by 1940	Residual load		
		Active	Marginal	Abandoned	Total				
Allegheny River	11, 730	250, 353	30. 565	124. 232	405, 150	29. 704	375, 446	3, 375	378. 821
Monongahela River	7, 380	580, 009	64, 673	275. 974	920, 656	274, 642	646, 014	7, 125	653, 139
Beaver River	3, 145	5, 480	988	10. 920	17, 388	2, 280	15. 108	8, 000	23. 108
Muskingum River [1]	8, 040	37, 700	14, 600	163, 500	215, 800	91, 400	124, 400	1, 375	125, 775
Little Kanawha River	2, 320	323	2	493	818	470	348		348
Hocking River	1, 185	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Kanawha River	12, 300	9, 210	995	22, 650	32, 855	13, 750	19. 105		19, 105
Guyandot River	1, 670	15, 680	614	3, 890	20, 184	9, 320	10, 864		10, 864
Big Sandy River	4, 280	16, 236	8, 997	35, 699	60, 932	14, 738	46, 194		46, 194
Scioto River	6, 510	4, 900	2, 400	16, 800	24, 100	6, 230	17, 870		17. 870
Little Miami River	1, 755								
Licking River	3, 670				(2)		(2)		(2)
Miami River	5, 385							6, 875	6. 875
Kentucky River	6, 940	10, 900	3, 200	27, 800	41, 900	11, 433	30, 467		30. 467
Salt River	2, 890								
Green River	9, 220	26, 500	7, 900	42, 100	76, 500	15, 115	61, 385		61, 385
Wabash River	33. 100	26, 777	3, 174	79, 631	109, 582	47, 040	62. 542	250	62. 792
Cumberland River	18, 000	53, 610	13, 045	198, 115	264. 770	68, 862	195, 908		195, 908
Tennessee River	40, 600	4, 960	1, 145	32, 063	38, 168	16, 200	21, 968		21, 968
Virginia (unclassified)					18, 750		18, 750		18, 750
Ohio River (minor tributaries and direct drainage)	23, 780	67, 093	24, 152	139, 180	230, 430	53, 966	176. 464	15,000	191. 464
Total	203, 900	1,109,731	176, 450	1, 173, 052	2, 477. 983	655, 150	1, 822, 833	42, 000	1, 864, 833

[1] Values for Hocking River included in Muskingum River values.
[2] Slight.

TABLE 6.—*Distribution of acid wastes by States and subbasins—Ohio River Basin*—Continued

Basin and State	Drainage area (square miles)	Mine acid load—tons per year ($CaCO_3$ equivalent)						Pickle liquor free acid load, tons per year ($CaCO_3$ equivalent)	Total residual acid load, tons per year ($CaCO_3$ equivalent)
		Prior to sealing program (by status of mines)				Removed by mine sealing by 1940	Residual load		
		Active	Marginal	Abandoned	Total				
Alabama	6,810								
Georgia	1,490								
Illinois	11,440	356	1,804	411	2,571	214	2,357		2,357
Indiana	29,135	29,775	3,238	89,644	122,637	53,100	69,537	375	69,912
Kentucky	39,375	88,900	31,700	180,000	300,600	64,500	236,100	1,125	237,225
Maryland	430	535	79	847	1,461	342	1,119		1,119
Mississippi	385								
New York	1,955								
North Carolina	6,260								
Ohio	29,570	65,000	25,000	270,000	360,000	123,590	236,410	19,500	255,910
Pennsylvania	15,620	521,513	90,003	277,833	889,349	91,804	797,545	15,000	812,545
Tennessee	33,645	25,170	5,190	160,478	190,838	59,800	131,038		131,038
Virginia (unclassified)	7,175				18,750		18,750		18,750
West Virginia	20,610	378,502	19,436	193,839	591,777	261,800	329,977	6,000	335,977
Total	203,900	1,109,731	176,450	1,173,052	2,477,983	655,150	1,822,833	42,000	1,864,833

B. EFFECTS OF POLLUTION

51. *Stream sanitary standards.*—Physical, chemical, and bacteriological considerations establish the relative desirability of waters for various uses. Table 7 summarizes the relationships between these factors.

TABLE 7.—*Water quality characteristics, Ohio River Basin*

Characteristic	Occurrence	Desirable	Doubtful	Unsuitable
		Water supply—General sanitary conditions		
Coliform bacteria per milliliter	Average	Not over 50 in any month (filtration treatment required if over 0.5).	50-200 in any month (unsuitable if greater than 200 in more than 5 percent of samples).	Over 200 in any month.
		Bathing—Recreation		
Coliform bacteria per milliliter	Average Maximum	Not over 1.0 Not over 10.0	1.0-10.0	Over 10.0.
		Fish life—Recreation—General sanitary conditions		
Dissolved oxygen, parts per million.	Average Minimum	Not less than 6.5 in any month Not less than 5.0 on any day	5.0[1]-6.5 in any month 3.0-5.0 on any day	Less than 5.0 in any month.[1] Less than 3.0 on any day.
		General sanitary conditions—Recreation		
5-day, 20° C., biochemical oxygen demand, parts per million.	Average	Not over 3.0 in any month	3.0-5.0 in any month	Over 5.0 in any month.
		Water supply—Fish life—Recreation—Navigation—Industry		
pH		6.5-8.6	4.0-6.5 or 8.6-9.5[2] (suitable for water supply prior to treatment).	Less than 4.0 or over 9.5[2] (unfavorable for water supply prior to treatment).
		Fish life—Recreation—General sanitary conditions		
Sludge deposits		No preventable deposits present	Slight to moderate—localized	Moderate to heavy—general.

[1] In general it may be said that a 5 parts per million minimum is desirable, except where local conditions may be favorable to allowing a 4 parts per million minimum in limited zones immediately below fairly isolated sources of pollution. See discussion, p. 34, pt. II, vol. I.

[2] Tentative drinking-water standards permit pH 10.6 in "treated" water.

TABLE 7.—*Water quality characteristics, Ohio River Basin*—Continued

Characteristic	Occurrence	Desirable	Doubtful	Unsuitable
		Water supply		
Phenols, parts per billion		Not over 1	1–10	Over 10.
		Water supply—Recreation—Fish life		
Other conditions		No toxic substances, oils, tars, or free acid at any time; no floating solids or debris, except from natural sources; no taste-producing substances.	Free acidity at any time, chlorides over 250 parts per million; occasional taste-producing substances.	Toxic substances, oils, or tars present at any time; free acidity present frequently; taste-producing substances present frequently.

52. In view of the variety, distribution, and extent of surface water uses, it is undesirable to establish rigid stream quality standards for general application in the Ohio River Basin, and the data in table 7 are not to be applied in that manner. The public interest can be served only by adapting standards to conditions existing in individual stream reaches, and by giving consideration to the most valuable stream use. However, a comparison between the observed quality of streams of the Ohio River Basin and the standards of table 7 affords a qualitative measure of the intensity of stream pollution throughout the basin.

53. *Extent of pollution.*—In terms of the highest of the water quality standards of table 7, stream pollution of severe intensity exists at points in all major tributary basins, in minor tributary basins, and on the main Ohio River. Table 8 summarizes the worst stream conditions found at more than 2,000 sampling stations in the Ohio River Basin, as indicated by monthly average coliform bacteria and biochemical oxygen-demand observations.

Plates 2 to 49 graphically indicate sources of pollution and dissolved oxygen and coliform bacteria results for the main Ohio River and all major and minor tributaries. Plates 15 and 19 also indicate the hydrogen ion concentration of streams of the Allegheny and Monongahela River Basins.

TABLE 8.—*Number and percentage of sampling stations showing worst monthly average coliform bacteria and biochemical oxygen demand results in designated ranges, Ohio River Basin*

Basin	Number of stations						Percentage of stations					
	Coliform organisms per milliter			Biochemical oxygen demand in parts per million			Coliform organisms per milliter			Biochemical oxygen demand in parts per million		
	0–50	51–200	Over 200	0–3	3.1–5.0	Over 5	0–50	51–200	Over 200	0–3	3.1–5.0	Over 5
Allegheny River:												
Acid streams	73	4	2	59	16	4	92	5	3	75	20	5
Normal streams	91	30	38	121	15	23	57	19	24	76	9	15
Total	164	34	40	180	31	27	69	14	17	76	13	11
Monongahela River:												
Acid streams	48	7	10	45	2	18	74	11	15	69	3	28
Normal streams	29	20	44	70	6	17	31	22	47	75	7	18
Total	77	27	54	115	8	35	49	17	34	73	5	22
Muskingum River:												
Acid streams	2	2	1	5	0	0	40	40	20	100	0	0
Normal streams	33	33	42	86	9	13	31	31	38	80	8	12
Total	35	35	43	91	9	13	31	31	38	80	8	12
Hocking River:												
Acid streams	5	1	3	4	3	2	56	11	33	45	33	22
Normal streams	6	3	9	6	3	9	33	17	50	33	17	50
Total	11	4	12	10	6	11	41	15	44	37	22	41
Kanawha River:												
Acid streams	6	1	1	6	1	1	75	12	13	75	12	13
Normal streams	74	26	42	106	16	20	52	18	30	75	11	14
Total	80	27	43	112	17	21	53	18	28	75	11	14

TABLE 8.—*Number and percentage of sampling stations showing worst monthly average coliform bacteria and biochemical oxygen demand results in designated ranges, Ohio River Basin*—Continued

Basin	Number of stations						Percentage of stations					
	Coliform organisms per milliter			Biochemical oxygen demand in parts per million			Coliform organisms per milliter			Biochemical oxygen demand in parts per million		
	0–50	51–200	Over 200	0–3	3.1–5.0	Over 5	0–50	51–200	Over 200	0–3	3.1–5.0	Over 5
Beaver River	21	15	29	35	13	17	32	23	45	54	20	26
Little Kanawha River	0	5	5	7	1	2	0	50	50	70	10	20
Guyandot River	16	5	7	17	6	5	57	18	25	61	21	18
Big Sandy River	33	18	37	64	10	14	38	20	42	73	11	16
Scioto River	32	15	38	37	17	30	38	17	45	44	20	36
Little Miami River	5	2	28	6	11	18	14	6	80	17	31	52
Licking River	24	7	3	19	13	12	71	21	8	43	30	27
Miami River	12	18	37	21	29	29	18	27	55	26	37	37
Kentucky River	32	20	29	52	11	18	39	25	36	64	14	22
Salt River	12	4	9	9	6	10	48	16	36	36	24	40
Green River	31	1	14	36	0	10	67	2	31	78	0	22
Wabash River	102	46	122	94	62	114	38	17	45	35	23	42
Cumberland River	45	27	39	73	19	18	41	24	35	66	17	17
Tennessee River	55	33	61	97	17	36	37	22	41	65	11	24
Tributary basin totals	787	343	650	1,075	286	440	44	19	37	60	16	24
Ohio River and minor tributaries:												
Pittsburgh to Huntington	23	43	36	72	7	23	23	42	35	70	7	23
Huntington to Cincinnati	6	8	14	21	4	3	22	28	50	75	14	11
Cincinnati to Louisville	4	9	20	10	14	9	12	27	61	30	43	27
Louisville to mouth	31	20	23	47	11	14	42	27	31	66	15	19
Ohio River and minor tributary basins totals	64	80	93	150	36	49	27	34	39	64	15	21

54. *Coliform bacteria results.*—Undesirable bacterial contamination of the streams of the Ohio River Basin is the most widespread effect of pollution. Limited stream reaches in which monthly average coliform bacteria counts of 200 or more per milliliter were observed are common to practically all portions of the basin and such counts were observed at 37 percent of the sampling stations. These reaches are unsuitable for use for public water supply, bathing, and recreation, and general sanitary conditions are poor. Monthly average coliform counts of over 50 per milliliter were common, and were observed at 58 percent of the sampling stations. Waters of the latter quality are unsuitable for bathing and recreational use, and are of doubtful value as sources of public water supply.

55. *Biochemical oxygen demand results.*—One or more monthly averages of biochemical oxygen demand of more than 5.0 parts per million were observed at 24 percent of the sampling stations. Stream reaches involved were uniformly distributed throughout the basin and generally corresponded to, but were of lesser extent than, those showing evidence of severe bacterial pollution. The general sanitary condition of these reaches is unsatisfactory.

56. *Dissolved oxygen results.*—In general, dissolved oxygen results confirmed the coliform bacteria counts and biochemical oxygen demand results in indicating polluted areas in the basin. During the periods of sampling, monthly average results below 5.0 parts per million were observed in limited stream reaches in all portions of the basin, and results below 4.0 parts per million were observed less frequently,

but particularly where organic waste concentrations were high in relation to available discharge. Such results are indicative of poor sanitary conditions.

57. *Hydrogen ion concentration.*—The effects of acid pollution were evidenced by high hydrogen ion concentrations observed primarily in the Monongahela and lower Allegheny River Basins and in localized tributary areas in the upper portion of the Ohio River Basin. Monthly average pH values less than 4.0 were observed in these areas. Values in this range are indicative of hard, corrosive waters, unsuitable for public and industrial water supplies and recreational use, and damaging to navigation structures.

58. *Damages resulting from stream pollution.*—While the intensity of stream pollution is severe in numerous localities, serious damage is confined to a few places where water use is extensive. Generally, pollution in tributary basins does not materially affect the Ohio River. An exposition of the important damages resulting from stream pollution follows.

59. *Damage to public health.*—Of the 634 surface water supplies in the Ohio River Basin, 294 are subject to some degree of pollution by human sewage. The latter surface supplies serve 5,865,800 persons and aggregate 571,000,000 gallons per day.

60. Conquest of water-borne typhoid fever has been virtually completed by the installation of adequate water treatment facilities at a majority of communities. There remains an epidemic disease, generally considered to be water-borne, and usually referred to as "gastro-enteritis, presumably water-borne."

61. Drinking water contaminated with small amounts of sewage can result in acute gastro-enteritis. Outbreaks from this cause occurred more frequently several decades ago than they do at present, and were often followed by typhoid fever infection. However, filtration and chlorination of public water supplies have not reduced the diarrhea and enteritis death rate to the same extent that these measures have reduced the typhoid fever death rate. Typical gastro-enteritis epidemics, traced to water supplies in 14 widely distributed communities in the United States, during the period 1924 to 1940, affected 240,000 people. The population exposed was 2,580,000. One of these epidemics occurred in the Ohio River Basin at Georgetown, Ky., during the period of the survey; 4,500 people were exposed; 50 percent were attacked. The epidemic lasted for 5 days. The diarrhea and enteritis death rates for 144 Ohio River Basin communities ranged from zero to 91.3 per 100,000 persons per year, during the period 1933 to 1937. The median rate was 14.8 per 100,000 persons per year.

62. Because water treatment alone has not provided full insurance against outbreaks of water-borne gastro-enteritis, it follows that stream pollution, particularly by domestic sewage, presents a definite hazard to public health. Fear of gastro-enteritis and dissatisfaction with public water supplies which it engenders are undesirable, and the man-hours lost during epidemics are of economic importance.

63. There are few stream reaches in the Ohio River Basin, physically suited to bathing and other recreational purposes, which are not below sources of untreated human sewage. Monthly average coliform bacteria counts of 50 or more per milliliter were observed at 1,166 sampling stations in the basin. A majority of the reaches embraced

by the remaining 851 sampling stations were also indicated to be of doubtful value for bathing purposes.

64. Many excellent facilities for bathing purposes are available in the basin, but, in view of the widespread bacterial pollution, it must be concluded that indiscriminate use of the streams for this purpose would constitute a dangerous hazard to public health.

65. The deposition of sewage solids along stream banks below sewer outfalls is a common occurrence in the basin, particularly in smaller tributary areas. These depositions constitute a source of disease which may be transmitted by flies or other insects.

66. *Damage to public water supplies.*—Public demand for safe water supplies of high quality precludes use of most surface waters without some prior treatment thereof. The removal of turbidity constitutes the major treatment applied to many unpolluted supplies. Disinfection is commonly practiced to insure bacterial quality. Stream pollution of domestic and industrial origin has in many cases necessitated more costly and extensive treatment, including softening, taste and odor removal, heavier chemical dosage, and hydrogen ion control. With the exception of bacterial pollution of public water supplies, the most widespread damages have been caused by acid wastes which result in hard corrosive waters. In numerous cases, particularly those involving tastes and odors, extensive treatment fails to produce a palatable water.

67. *Damage to industrial water supplies.*—The bulk of industrial water use in the Ohio River Basin is for cooling and wash water purposes. Basic requirements for satisfactory cooling water, other than low temperature, are freedom from turbidity and corrosiveness. Acid pollution has considerably damaged cooling water supplies in the upper Ohio River area by increasing the corrosiveness of surface waters. Wash water supplies have not been seriously affected. More specialized water uses, such as boiler supply, have also been adversely affected by acid pollution.

68. *Damage to navigation and hydroelectric power structures.*—Excessive corrosion of floating and stationary navigation structures and hydroelectric power facilities has resulted primarily from acid pollution in the upper Ohio River Basin. The decrease effected in the life of such structures is a positive economic damage chargeable to stream pollution.

69. *Damage to aquatic recreational facilities.*—The major damage to aquatic recreational facilities such as swimming is bacterial pollution. However, oxygen depletion resulting from organic industrial wastes and sewage, and acidity resulting from inorganic wastes, have caused conditions unsuitable for the support of aquatic life in many streams. Sporadic pollution has also been responsible for fish killings in numerous localities.

70. *Local nuisance.*—In metropolitan areas, the aesthetic value of streams is usually slight, largely as a result of stream appurtenances provided for commerce rather than beauty. However, in such areas, there are frequently obnoxious odors resulting from the decomposition of sewage, and unsightly conditions resulting from sleek, scum, floating solids, and stream discoloration. These are commonly classified as local nuisance conditions and are responsible for a large portion of the public desire for pollution control.

71. Local nuisance conditions are common to a majority of the sewered communities in the Ohio River Basin which do not have sewage-treatment facilities, particularly those where stream flows are low in comparison with pollution loads.

72. Destruction of aesthetic values in rural areas is largely related to other stream uses. The attractiveness of streams for recreational use appears to suffer because of a public aversion to unsightly conditions resulting from other than natural causes. The Clarion River, polluted by industrial wastes, and many upper-basin tributaries of the Ohio River, polluted by mine drainage, are typical examples of this condition.

73. *Summary of damages.*—Principal damages from stream pollution are to public health, domestic and industrial water supply, recreation, navigation, plant and animal life, other water uses, and aesthetic values.

74. Untreated domestic sewage damages mainly public health and water supplies, recreation, plant and animal life, and aesthetic values. Industrial wastes, by their variety, effect damages to all water uses, but, in general, have a lesser effect on public health than have domestic wastes.

75. The effects of stream pollution are widespread. In addition to direct, economic damages, there are other, less tangible damages, of a more or less psychological nature. For example, aquatic recreational facilities convenient to large population centers are of value to public morale, may lessen juvenile delinquency, and in other ways contribute to the general public welfare. It follows that their destruction by stream pollution is detrimental to public welfare in these respects.

76. Consideration of both the intensity and extent of individual cases of stream pollution in the basin indicates those discussed in the following paragraphs to be of major importance. A discussion of lesser pollution problems found in the various tributary basins and on reaches of the main river is contained in appendices to this report.

77. *Ohio River.*—The main Ohio River receives domestic and industrial pollutants at frequent intervals throughout its length, and all water supplies from this source are subject to bacterial pollution. Pollution is severe in the Pittsburgh, Cincinnati, and Louisville areas and in the reaches from Pittsburgh to Wheeling, and from Huntington to Portsmouth.

78. There are more intensely polluted stream reaches in the Ohio River Basin than those of the main stream. However, pollution damages in the main stream are more widespread, with the result that these are of major importance from a quantitative standpoint. Further importance attaches to large pollution sources such as those at Pittsburgh, Cincinnati, and Louisville and the Huntington-Portsmouth reach. These dominate stream conditions over relatively long reaches and treatment of their wastes is part of a logical first step in an Ohio River pollution control program.

79. *Pittsburgh, Pa.*—The organic waste load reaching the Ohio River from Pittsburgh and its suburbs has a population equivalent of 1,334,300, of which 597,200 discharges to the Allegheny, 458,500 discharges to the Monongahela, and 278,600 discharges to the Ohio River direct. When the residual organic waste load from population equivalents of 917,200 in the upper Allegheny River and 796,200 in

the upper Monongahela River is added to that from Pittsburgh and its suburbs, it becomes apparent that the concentration of organic waste below Pittsburgh is larger than that below any other community on the Ohio River proper. Additional pollution of significance includes 1,032,000 tons per year of acid waste (calcium carbonate equivalent) which flows from the area adjacent to and above Pittsburgh.

80. The normal bacterial effect of untreated human wastes apparently is masked by acid pollution of the upper Ohio River. However, coliform bacteria counts at Emsworth Dam, 6 river miles below Pittsburgh, varied from less than 1 to as high as 811 per milliliter in 39 samples collected from September 1940, to March 1941. The median count was 52, the average, 94 per milliliter. Ten percent of the samples had coliform bacteria counts in excess of 200 per milliliter. Water of this quality is unsuitable for domestic water supply and definitely dangerous for bathing purposes.

81. Partial oxygen depletion, denoting unsatisfactory sanitary conditions, was noted below Pittsburgh in October 1940. On the days of maximum oxygen depletion flows averaged four times as large as the minimum flows of record.

82. *Pittsburgh, Pa., to Wheeling, W. Va.*—There is serious pollution of the 90-mile reach of the Ohio River from Pittsburgh to Wheeling, by domestic and industrial wastes from 24 significant sources, spaced at rather uniform intervals. Bacterial pollution is a result, although the effects are masked by acid wastes, largely from coal mines.

83. Including that at Bellaire, Ohio, there are 8 public water supplies taken from the reach. These serve 173,600 people and aggregate 174,000,000 gallons per day. The average coliform bacteria count at the East Liverpool waterworks intake was 250 per milliliter for the period 1925 to 1940. All public water supply intakes are situated only 3 to 12 miles below significant waste sources. This is indicative of the insanitary conditions of the reach which constitute a serious potential source of damage to public health.

84. Extensive corrective measures are indicated. Situated at the head of the reach, Pittsburgh is the key to pollution control in the area and is the logical location for initial work in that connection.

85. *Huntington, W. Va., to Portsmouth, Ohio.*—Concentrations of wastes at 6 localities in the 50 mile Huntington to Portsmouth reach of the Ohio River result in bacterial pollution of public water supplies at Ashland, Ironton, and Portsmouth. The average coliform bacteria count at the Ironton waterworks was 125 per milliliter during the period 1925 to 1940. A maximum monthly average of 685 per milliliter has been observed at this plant. The intakes for all 3 supplies are within several miles of upstream pollution sources. Corrective measures are indicated as a safeguard to public health.

86. *Cincinnati, Ohio.*—In the Cincinnati area, the largest organic waste source on the main Ohio River, wastes having a population equivalent of 1,784,700 are discharged. These wastes are 64 percent industrial. Dissolved oxygen depletion and bacterial pollution at downstream points are the principal damaging effects.

87. During August and September 1939, dissolved oxygen results on 22 sampling dates varied betweeen 6.6 and 1.6 parts per million at dam No. 37, below Cincinnati. The median value was 4.9 and the average value 4.6 parts per million. These are indicative of unfavorable sanitary conditions. Discharge on the day of maximum

oxygen depletion was 3 times as great as the minimum flow of record; average discharge during the period was equal to the mean of minimum monthly flows. Monthly average coliform bacteria counts were observed to be consistently in excess of 200 per milliliter as far downstream as dam 39, 61.5 river miles below Cincinnati, during June, July, and August 1939. One or more monthly averages in excess of 50 per milliliter were observed at all stations between Cincinnati and Louisville.

88. *Louisville, Ky.*—Sewered wastes from 335,100 persons and an industrial waste population equivalent of 626,500 are discharged to the Ohio River in the Louisville area. This is the third largest pollution source on the stream. Discharge conditions are such that bacterial pollution of downstream reaches is the major damage effected.

89. The New Albany water supply, from the Ohio River in the Louisville area, is seriously degraded. Nine water samples collected during August and October 1940, and February 1941, at the plant intake, had coliform bacteria counts of from 93 to as high as 2,400 per milliliter. The median count was 430; the average count, 645. Streams in which monthly average counts exceed 200 per milliliter are considered unsuitable for public water supply. Monthly average coliform bacteria counts in excess of 50 per milliliter were observed during August 1940, as far downstream as Troy Hill Light, 127 river miles below Louisville. Water of this quality is unsuitable for public water supply and for extensive recreational use.

90. *Beaver River Basin.*—Concentration of population and industry in the Youngstown area on the tributary Mahoning River has caused severe stream pollution. Untreated sewage results in sludge bank formation, and floating solids, scum, and objectionable odors are common causes of complaints. Extensive use of water by the steel industry necessitates channel pondage, and results in high stream temperatures and low stream velocities; these, in conjunction with inadequate summer discharge, add to the severity of pollution.

91. Residents of the Mahoning River Valley, below Warren, have been forced to discontinue use of the river for public water supply because of stream pollution. Downstream Beaver River water supplies are subjected to bacterial pollution, and difficult taste and odor problems result from the discharge of phenols in the Youngstown area. In addition to creation of local nuisance conditions, other damages include complete destruction of aquatic recreational facilities in the Beaver and lower Mahoning Rivers. These are sorely needed in the basin, which has an average population density of 231 persons per square mile.

92. Low flow control from existing Milton and Pymatuning Reservoirs and building Berlin Reservoir will partially improve the situation; however, sewage treatment for Youngstown and vicinity, and industrial waste control, are necessary. Low flow control will permit smaller expenditures for this purpose than would otherwise be required, and its continuance is essential to satisfactory pollution abatement.

93. Need for pollution control is indicated at other localities in the basin, where pollution is of a more local significance.

94. *Kanawha River Basin.*—The chemical industry, situated mainly in the Charleston area of the Kanawha River Valley, is one of the major organic waste sources in the Ohio River Basin. Its wastes

have a human population equivalent of 1,378,000. Untreated domestic sewage contributes to the pollution, and serious nuisance conditions result. In addition to odors, unsightly conditions, and destruction of aquatic recreational facilities, damages include bacterial pollution of water supplies and serious taste and odor troubles.

95. Domestic and industrial waste treatment is indicated, and low flow control would prove valuable, particularly in Elk River which is a source of Charleston's public water supply.

96. *Other tributaries.*—Numerous stream reaches in tributary basins are seriously polluted, with local damage as the result. These generally are of lesser importance, relatively, than are those of the areas already discussed. Typical of the lesser pollution problems are the following:

(*a*) The Clarion River in the Allegheny River Basin is polluted in headwater reaches by industrial wastes, untreated sewage, and acid mine drainage. Damages include degradation of a stream otherwise ideal for recreational use. There are difficult industrial waste treatment problems.

(*b*) The upper Tuscarawas River in the Muskingum River Basin is materially polluted by industrial and domestic wastes. Domestic water supplies have been severely damaged.

(*c*) Streams of the lower Scioto River Basin are polluted by industrial and domestic wastes. This includes the main stream below Columbus where residual pollution and surface wash create difficulties despite the storm water tanks and the high degree of sewage treatment provided by the city of Columbus. Low natural discharge and present limitations on industrial waste treatment methods will complicate application of corrective measures.

(*d*) Heavy waste loading of the Miami River in the Dayton-Hamilton reach results in high coliform bacteria counts and biochemical oxygen demand, and oxygen depletion. Domestic waste residuals and paper mill wastes are the damaging pollutants.

(*e*) There are numerous badly polluted stream reaches in the Wabash River Basin which result from waste concentrations disproportionately high with regard to available flow. The most important of these is below Terre Haute where the untreated sewage from 26,000 persons, together with an organic industrial waste population equivalent of 347,400, is discharged to the Wabash River. Serious oxygen depletion and high coliform bacteria counts are common to the 30-mile reach below the city.

(*f*) Pollution of the Cumberland River in the Nashville area results in localized, downstream nuisance. Corrective measures are indicated. The Wolf Creek hydroelectric development now under construction upstream will lessen the difficulty of providing waste correction because of flow regulation which will result.

(*g*) The tributary Pigeon River in the Tennessee Basin is grossly polluted throughout its length, largely with organic industrial wastes. Damage results to the Knoxville water plant 78 miles below on the Tennessee River.

97. *Acid pollution of the upper Ohio River Basin.*—The bituminous coal fields of southwestern Pennsylvania and northern West Virginia are the major sources of acid wastes which are damaging to streams of the upper Ohio River Valley. The Allegheny River Basin as far north as the headwaters of the Clarion River and the Monongahela River Basin, with the exception of the tributary Tygart, Cheat, and

upper Youghiogheny River Basins, are severely polluted with acid mine drainage. Monthly average pH values of 4.0 or less, indicating a high hydrogen-ion concentration, are not uncommon in these areas. The effects of acid pollution are also evident in the Ohio River as far downstream as the mouth of the Kanawha River, 266 river miles below Pittsburgh. Free acid in waste pickle liquor discharged by metallurgical industries adds about 2.5 percent to the mine acid load. Acid from hydrolyzed iron sulfates in these wastes may be more significant, depending on the hydrolysis equilibrium.

98. Direct damages which result to public and industrial water supplies, power plants, and floating and stationary navigation structures and equipment in the upper Ohio River Basin alone, aggregate it is estimated, over $2,000,000 per year, and are imposed on industry and a population of several million. The aquatic and recreational facilities of a heavily populated and extensive area are damaged and acid pollution has been a deterrent to the application of domestic and industrial pollution control measures.

99. While partial relief has resulted from mine-sealing operations and low flow control from Tygart River Reservoir, the acid load continues to increase, and further corrective measures are indicated. It is estimated that unless acid control measures are applied average annual damages will increase by more than 50 percent by 1960.

VII. Future Conditions

100. The satisfactory practice of waste-disposal methods which include ultimate discharge to water bodies, depends on the relationship between the character, quantity, and strength of the wastes and the character and volume or discharge of the receiving body of water. Unless remedial measures are adopted, the future condition of streams in the Ohio River Basin depends on changes in present pollution loads and stream flow.

101. *Possible effects of population and industrial changes.*—A comparison between population growth in the Ohio River Basin and in the United States as a whole is shown in the following tabulation:

Year	Ohio River Basin		United States	
	Population	Percent increase over preceding period	Population	Percent increase over preceding period
1890	11,029,000		62,947,714	(25.5)
1900	12,755,000	16	75,994,575	20.7
1910	14,382,000	13	91,972,266	21.0
1920	15,898,000	11	105,710,620	14.9
1930	17,533,000	10	122,775,046	16.1
1940	18,816,000	7	131,669,275	7.2
1890–1940		72		109.2

102. For five decades the rate of population increase in the Ohio River Basin has been consistently less than that of the United States. The cities of the basin are more mature than those of the Nation as a whole, and the population is hence likely to reach a maximum at an earlier date. It is estimated that a peak of about 20,000,000 will

occur in the period between 1960 and 1970. This figure is 7 percent greater than the present population of the basin.

103. During the decade following 1930, the population of many Ohio River Basin communities decreased significantly for the first time. In the 10 States which have 5,000 or more square miles of area within the basin, over 25 percent of all incorporated communities became smaller during this period, and population losses were common to communities of all sizes. In view of the approaching peak in the population of the basin as a whole, losses which have already set in may continue in some communities, and, in general, a leveling off of population curves is to be expected in the remaining communities in the next 25 years.

104. Because of the small population growth anticipated, increased domestic sewage loads which will result should not materially increase the severity of pollution in the Ohio River or its major tributaries. Significant increases may be confined generally to a 25-year period and to those smaller streams in which waste loading is already high relative to the volume of diluting water available. In the past, sewage treatment facilities have been provided at the sites of some of the most severe pollution problems. Continuation of this procedure will reduce the effect of anticipated increases in population.

105. Industrial activity is related to population growth, and it is probable that, for the basin as a whole, a stabilized population will result in an economy of replacement rather than an economy of rapid expansion. It seems reasonable to estimate that no material changes in industrial waste pollution will result for some time. About half of the organic industrial waste load now comes from food processing, paper, and strawboard plants. Pollution from these sources probably will increase with population and reach a peak within a few decades. Chemical industries now discharge 21 percent of the industrial waste population equivalent not served by municipal treatment. New products have been developing in this field and an increase in wastes may be anticipated. It is estimated that future industrial waste pollution will increase in rough proportion to that from domestic sources for the basin as a whole. However, development of new processes and products in any major industry may change this relationship.

106. Pollution by acid mine drainage is increasing in intensity in rough proportion to the accumulative tonnage of coal already mined. Therefore, continued but less rapid increases in mine acid loads may be expected indefinitely, even after stabilization of population and industrial development and of the domestic coal market. In the case of significant industrial pollutants, this condition occurs only in mine drainage. The rate of increase in mine acid loads will vary largely with world conditions influencing coal consumption and with industrial development and activity.

107. *Possible effects of changes in discharge conditions.*—Discharge of the streams of the Ohio River Basin is influenced by the quantity, extent, distribution, and intensity of rainfall and by regulation in impounding reservoirs. Canalization modifies discharge elements such as velocity and stream cross section, but, alone, does not appreciably affect the discharge volumes.

108. *Droughts.*—A wave of epidemic gastro-enteritis occurred in the Ohio River Valley after the 1930 drought. There is evidence that the outbreaks were water-borne. Gastro-enteritis first was noted in Charleston, W. Va., late in October 1930, and lasted until about

November 10, 1930. Later in the year, there were rains in the Kanawha River Basin which flushed the channel at and below Charleston. Early in January 1931, gastro-enteritis was simultaneously noted at Huntington, W. Va., Ashland, Ky., and Ironton, Ohio, all on the Ohio River below the mouth of the Kanawha River. The attacks lasted until about January 10, 1931. Cincinnati experienced the same complaint from mid-January 1931 to about February 1, 1931. Louisville was affected on about January 25, 1931. The chronological order of attack indicates a progressive downstream movement of the causative agent.

109. The drought of 1930 was also notable for the obnoxious tastes and odors experienced in many public water supplies in the basin. These frequently caused water users to seek more palatable supplies, often of questionable sanitary quality. Thus, the drought created a material potential source of damage to public health. In many instances, sewer outfalls were uncovered during periods of low river stage, as were sludge banks. This created many local nuisance problems. Widespread pollution of the streams of the Ohio River Basin added to the difficulty of quickly developing emergency water supplies at those communities where the normal supply became inadequate.

110. The low flow conditions of this period apparently have not been duplicated on a basin-wide scale during nearly a century. The following tabulation indicates their severity in the Ohio River at Cincinnati:

Minimum monthly flow during 1930	3,600 cubic feet per second.
Mean of minimum monthly flows for years 1920 to 1940, inclusive.	21,500 cubic feet per second.
Ratio, minimum to mean of minimums	1 to 6.
Average June to September flow during 1930	7,700 cubic feet per second.
Average June to September flow for years 1920 to 1940, inclusive.	48,200 cubic feet per second.
Ratio, average 1930 to average for period	1 to 6.

111. In 31 humid States, including the 14 which comprise the Ohio River Basin, noticeable rainfall deficiencies occur at from 3- to 7-year intervals. Generally, the deficiencies are confined to short periods, with the result that discharge deficiencies of more than several months' duration are uncommon. In the 1920-40 period, during the latter half of which the average summer flow of the Ohio River was unusually low, minimum monthly summer discharges occurred as shown in the following tabulation:

Month	Year of occurrence and discharge in cubic feet per second							
	Lowest		Second lowest		Third lowest		Fourth lowest	
	Year	Discharge	Year	Discharge	Year	Discharge	Year	Discharge
June	1930	15, 200	1934	16, 300	1936	21, 100	1925	24, 500
July	1930	6, 500	1934	15, 900	1936	22, 100	1933	26, 100
August	1930	4, 300	1936	18, 500	1932	19, 700	1929	22, 800
September	1930	4, 700	1939	12, 900	1932	14, 800	1936	15, 600
October	1930	3, 600	1938	13, 600	1933	14, 300	1940	15, 600
November	1930	5, 300	1931	16, 200	1939	24, 400	1924	31, 700
Composite average	-----	6, 600	-----	15, 600	-----	19, 400	-----	22, 700

It is of significance that, with the exception of 1930, unusually low flow conditions were not observed in more than 2 consecutive months during the period. The probability of the recurrence of a long sequence of months with discharges as low as those of 1930 appears to be remote. It should also be noted that the composite average of second lowest flows (second column above) was 136 percent greater than the average for June to November 1930 (first column above). The spread between averages of the lowest and second lowest natural June-to-November flows (6,600 cubic feet per second, 1930; 25,800 cubic feet per second, 1934) is 291 percent.

112. Drought damages are often widespread. However, with the exception of extremely severe droughts, accompanied by prolonged periods of low flow, their effect on stream pollution is comparatively minor.

113. *Reservoirs.*—Reservoirs, provided for flood-control purposes only, have slight effect on stream quality. Their major purpose is the rearrangement of the natural regimen of discharge during periods of extremely high flow. At high water oxygen depletion and nuisance conditions, resulting from sewage and pollution by industrial waste discharges, usually are not serious. However, the provision of low-flow control as a supplementary feature of storage reservoirs provided for flood control usually has a beneficial effect on the sanitary condition of downstream reaches. Reservoirs at which hydroelectric power is generated almost always produce an incidental beneficial effect on stream sanitation, and water-supply reservoirs frequently have a beneficial effect. Provisions to increase low flow have been considered by the Corps of Engineers in the prosecution of a comprehensive flood-control plan for the Ohio River Valley. Reservoir projects built or now under construction by the Corps of Engineers to provide flood control, low-flow control, and other benefits, are as follows:

Reservoir	Basin	Purpose
Built: Tygart, Tygart River	Monongahela River	Flood control, navigation water supply (low-flow control).
Under construction:		
Youghiogheny, Youghiogheny River	do	Flood control, low-flow control.
Berlin, Mahoning River	Beaver River	Do.
Bluestone, Kanawha River	Kanawha River	Flood control, hydroelectric power production, low-flow control.
Wolf Creek, Cumberland River	Cumberland River	Do.
Dale Hollow, Obey River	Cumberland River	Do.
Center Hill, Caney Fork River	Cumberland River	Do.

114. Normally, seasonal low-flow control may be provided at small additional cost as an incidental feature of flood-control storage developments. Hence there is no economic bar to its further provision where flood-control storage works are justified. The increased discharge during periods of low run-off made possible by low-flow regulation is likely to be, in many cases, an effective adjunct to sewage treatment and, in connection with flood-control reservoir developments, is conducive to efficient use of the water resources of the basin.

115. The probable effects of the reservoirs now built or under construction on low water discharge are summarized in table 9.

TABLE 9.—*Probable effect of low-water discharge of reservoirs now built or under construction, Ohio River Basin*

Reservoirs and key river stations [1]	Low-water regulation features							
	Maximum reservoir capacity available for low-water regulation, acre-feet	Discharge station	Average discharge during June to November 1930, cubic feet per second					Incidence of increase on Ohio River, miles below Pittsburgh, Pa.
			Natural	Probable regulated	Probable increase		Cumulative increase	
	Low-water regulation effect of individual reservoirs							
						Percent		
A. Tygart Reservoir	100,000	Damsite	23	340	317		317	0
B. Youghiogheny Reservoir	149,000	do	49	480	431		748	0
C. Berlin Reservoir	23,000	Youngstown, Ohio	[2] 110	[3] 160	50		798	25.6
D. Bluestone Reservoir	[4] 245,000	Damsite	1,290	2,000	710		1,508	265.7
E. Wolf Creek Reservoir	[4] 2,017,000	Nashville, Tenn. (E, F, G)	1,490	6,950	5,460		6,968	920.4
F. Dale Hollow Reservoir	[4] 473,000							
G. Center Hill Reservoir	[4] 492,000							
	Low-water regulation effect at key discharge stations							
Tributaries:								
Monongahela River	Reservoirs A and B	Pittsburgh, Pa.	[5] 1,150	1,898	748	65		
Mahoning River	Reservoir C	Youngstown, Ohio	[2] 110	[3] 160	50	45		
Kanawha River	Reservoir D	Kanawha Falls, W. Va.	1,590	2,300	710	45		
Cumberland River	Reservoirs E, F, and G	Nashville, Tenn.	1,490	6,950	5,460	365		
Ohio River	Reservoirs A and B	Pittsburgh, Pa.	3,230	3,978	748	23		
Do	Reservoirs A, B, C, and D	Cincinnati, Ohio	6,600	8,108	1,508	23		
Do	do	Louisville, Ky.	9,220	10,728	1,508	16		

[1] Reservoirs under the jurisdiction of the Corps of Engineers.
[2] Probable discharge had existing non-Federal Milton Reserve been used to sustain highest possible value of minimum flow at Youngstown, Ohio.
[3] Probale discharge with combined operation of Berlin and Milton Reservoirs.
[4] Maximum draw-down for power purposes.
[5] Estimated.

116. At the head of the Ohio River, the average increase in minimum flow from Tygart, Youghiogheny, and Berlin Reservoirs will approximate 43 percent of the July to November flows of 1930. Bluestone Reservoir will result in an additional increase in the flow of the upper Ohio River, resulting in a 31-percent improvement in minimum discharge at Cincinnati. Proportionately larger increases would be effected on the tributaries on which the reservoirs are situated. Because of these reservoirs, it is possible that flows as low as those of 1930 will never again be experienced in the Ohio River.

117. Other reservoirs of the present comprehensive flood-control plan for the Ohio River, possible alternate reservoirs, and possible additions to the plan, would be capable of providing low flow control in tributary basins and the main stream. However, where detailed studies have been made, economic considerations generally indicate the provision of low flow control as an incidental rather than a primary function of reservoir development.

118. Low flow-control operations incidental to flood control are subject to limitations imposed by restrictions on the use of storage capacity and it is probable that the most significant future increases in low water flow will result from flood control-hydroelectric reservoir development, in which case increases in low water flow will occur incidentally to hydroelectric operations. Table 10 lists certain reservoir projects of significance with respect to low flow control, which may be provided in the Ohio River Basin, together with their possible low flow-control features.

TABLE 10.—*Possible effect on low-water discharge of reservoirs considered for development of Ohio River Basin*

Reservoirs and key river stations [1]	Possible low-water regulation features						
	Maximum reservoir capacity available for low-water regulation, acre feet [2]	Discharge station	Average discharge during June to November 1930, cubic feet per second: Natural	Possible regulated	Possible increase		Accumulative increase	Incidence of increase on Ohio River, miles below Pittsburgh, Pa.
	Possible low-water regulation effect of individual reservoirs							
						Percent		
H. Allegheny River Reservoir	520,000	Dam site	225	1,925	1,700	--------	1,700	0
I. Clarion River Reservoir [3]	618,000	do	104	1,060	956	--------	2,656	0
J. Cheat River Reservoir	576,000	do	51	581	530	--------	3,186	0
K. Shenango River Reservoir	25,000	do	(4)	(4)	[4] 100	--------	3,286	25.6
L. Summersville Reservoir (Gauley River, W. Va.)	240,000	do	17	630	613	--------	3,899	265.7
M. Cave Run Reservoir (Licking River, Ky.)	625,000	Falmouth dam site	10	2,050	2,040	--------	5,939	470.2
N. Falmouth Reservoir (Licking River, Ky.)	960,000							
O. Booneville Reservoir (South Fork Kentucky River, Ky.)	193,000	Jessamine dam site	174	1,075	901	--------	6,840	545.8
P. Jessamine Reservoir (Kentucky River, Ky.)	285,000							
Q. No. 2 Barren Reservoir (Barren River, Ky.)	558,000							
R. Nolin Reservoir (Nolin River, Ky.)	177,000	Mining City dam site	599	2,300	1,701	--------	8,541	784.2
S. Mining City Reservoir (Green River, Ky.)	27,000							
T. Stewarts Ferry Reservoir (Stones River, Tenn.)	172,000	Nashville, Tenn.	[5] 6,950	7,400	450	--------	8,991	920.4
U. Three Islands Reservoir (Harpeth River, Tenn.)	152,000	Damsite	180	450	270	--------	9,261	920.4

[1] Reservoirs under consideration by the Corps of Engineers.
[2] Maximum draw-down for power purposes shown for contemplated flood control-hydroelectric developments.
[3] Present quality of Clarion River unfavorable for low water regulation use as an initial development.
[4] Operation dependent on operation of existing, non-Federal Pymatuning Reservoir. Plan contemplates addition of 100 cubic feet per second to regulated flow during June to September, inclusive.
[5] Includes probable regulation by Wolf Creek, Dale Hollow, and Center Hill Reservoirs.

TABLE 10.—*Possible effect on low-water discharge of reservoirs considered for development of Ohio River Basin*—Continued

Reservoirs and key river stations [1]	Possible low-water regulation features							
	Maximum reservoir capacity available for low-water regulation, acre feet	Discharge station	Average discharge during June to November 1930, cubic feet per second					Incidence of increase on Ohio River, miles below Pittsburgh, Pa.
			Natural	Possible regulated	Possible increase		Accumulative increase	
	Possible low-water regulation effect at key discharge stations							
Tributaries:						*Percent*		
Allegheny River	Reservoirs H and I	Pittsburgh, Pa	2,180	4,836	2,656	122		
Monongahela River	Reservoir J	do	[6] 1,898	2,428	530	28		
Shenango River	Reservoir K	Sharon, Pa	[7] 200	300	100	50		
Kanawha River	Reservoir L	Kanawha Falls, W. Va	[8] 2,300	2,913	613	27		
Licking River	Reservoirs M and N	Falmouth, Ky	10	2,050	2,040	20,400		
Kentucky River	Reservoirs O and P	Warwick, Ky	213	1,114	901	423		
Green River	Reservoirs Q, R, and S	Livermore, Ky	618	2,319	1,701	276		
Cumberland River	Reservoir T	Nashville, Tenn	[5] 6,950	7,400	450	6		
Ohio River	Reservoirs H, I, and J	Pittsburgh, Pa	[6] 3,978	7,164	3,186	80		
Do	Reservoirs H, I, J, K, L, M, and N.	Cincinnati, Ohio	[9] 8,108	14,047	5,939	73		
Do	Reservoirs H, I, J, K, L, M, N, O, and P.	Louisville, Ky	[9] 10,728	17,568	6,840	63		

[1] Reservoirs under consideration by the Corps of Engineers.
[5] Includes probable regulation by Wolf Creek, Dale Hollow, and Center Hill Reservoirs.
[6] Includes probable regulation by Tygart and Youghiogheny Reservoirs.
[7] Includes estimated effect of non-Federal Pymatuning Reservoir.
[8] Includes probable regulation by Bluestone Reservoir.
[9] Includes probable regulation by Tygart, Youghiogheny, Berlin, and Bluestone Reservoirs.

119. It must be recognized that the foregoing estimates are subject to modification by virtue of changing power markets, conditions of stream pollution, and future economic conditions. It is believed that they indicate the possible extent of low flow-control operations in the Ohio River Basin in the future. Provision of all the reservoirs listed, together with those now built or under construction, would have resulted in an increase in minimum flow of 220 percent in 1930, at the head of the Ohio River, and of 140 percent at Cincinnati. While such discharge increases would materially improve sanitary conditions along tributaries and the main stream, in general, the need for sewage treatment would not be eliminated, because bacterial pollution would continue. On the other hand, the flow increases would be, in places, sufficient to reduce the extent and cost of sewage and industrial waste treatment needed to prevent undue depletion of dissolved oxygen and also, along small streams, to supplement complete treatment.

120. Review of Ohio River water-plant records discloses that in the last 15 or 20 years there has been no general depreciation in the quality of the stream at the larger waterworks intakes. The most noteworthy change in water quality was a progressive decrease in the natural alkalinity of the river experienced at upstream water plants. However, at and below Steubenville, Ohio, this trend was not in evidence. At Cincinnati, Ohio, higher than average coliform bacteria counts were observed during the period 1935 to 1940. This condition appears not to have occurred elsewhere. While it is certain that increases in domestic and industrial waste loadings experienced during the last 15 to 20 years resulted in more severe pollution in localized reaches, serious effects of this additional pollution were not in evidence at all waterworks on the river. Table 11 is a tabulation of coliform bacteria, alkalinity, and turbidity results for Ohio River water at selected waterworks intakes.

TABLE 11.—*Water quality at waterworks intakes, Ohio River Basin*

Location	East Liverpool				Steubenville				Ironton			
Miles below Pittsburgh	43				69				328			
Period considered	1925 to 1929	1930 to 1934	1935 to 1940	1925 to 1940	1925 to 1929	1930 to 1934	1935 to 1940	1925 to 1940	1925 to 1929	1930 to 1934	1935 to 1940	1925 to 1940
Coliform bacteria per milliliter:												
Maximum	1,180	679	1,003	1,180	538	234	96	538	527	685	340	685
Average—June to September	99	134	370	183	42	30	19	30	206	157	144	165
Average	169	208	379	250	25	24	17	22	179	103	107	125
Alkalinity, parts per million:												
Maximum	28	30	16	30	14	35	25	35	49	51	50	51
Average—June to September	13	7	8	9	9	8	11	9	37	31	35	34
Average	13	10	8	11	9	8	10	9	30	28	29	29
Turbidity, parts per million:												
Maximum	450	185	900	900	430	230	330	430	380	400	435	435
Average—June to September	67	36	115	70	31	50	101	66	131	101	146	127
Average	115	61	191	124	71	60	83	73	143	113	157	139

TABLE 11.—*Water quality at waterworks intakes, Ohio River Basin*—Continued

Location	Cincinnati				Louisville				Evansville			
Miles below Pittsburgh	470				609				797			
Period considered	1925 to 1929	1930 to 1934	1935 to 1940	1925 to 1940	1925 to 1929	1930 to 1934	1935 to 1940	1925 to 1940	1925 to 1929	1930 to 1934	1935 to 1940	1925 to 1940
Coliform bacteria per milliliter:												
Maximum	135	120	335	335	120	167	131	167	------	------	------	------
Average—June to September	42	30	124	68	20	22	23	22	------	------	------	------
Average	32	28	104	57	27	19	22	22	------	------	------	------
Alkalinity, parts per million:												
Maximum	58	72	59	72	83	96	82	96	90	109	92	109
Average—June to September	42	40	43	42	62	53	56	57	71	71	68	70
Average	36	38	37	37	55	52	51	53	60	63	60	61
Turbidity, parts per million:												
Maximum	500	370	490	500	600	590	610	610	510	630	530	630
Average—June to September	182	104	147	145	132	76	103	104	161	80	128	123
Average	234	122	144	166	201	118	158	159	226	142	167	177

NOTE.—Monthly average values obtained from waterworks data and not reported on a uniform basis.

121. *Navigation improvements.*—The 1914, 1930, and current Ohio River pollution surveys indicate no definite trend in river water quality traceable directly to the construction and operation of navigation facilities. However, stream canalization has definite effects on stream conditions which in turn influence water quality. Among these the following are of importance:

(*a*) Stream velocities are lessened, thus increasing times of flow and tending to shorten the zones of bacterial pollution which may exist below sewer outfalls. This is a beneficial effect of navigation improvements. A detrimental effect of lessened velocities is a tendency toward the precipitation of sewage solids and resultant sludge bank formation.

(*b*) Stream turbulence is decreased throughout long reaches, thus lessening the rate at which oxygen is absorbed from the air. This is a detrimental effect of navigation improvements.

(*c*) Navigation dams result in localized areas of turbulent discharge which tend to offset loss of the natural turbulence of flow. This effect of navigation improvements is beneficial.

(*d*) Stream depths are increased, resulting in a tendency toward decreased light penetration and lessened oxygen recovery from photosynthesis; however, this condition is offset by lessened turbidity which tends to permit greater light penetration. Stream characteristics are subject to complicated but compensating influences as a result of canalization. On the whole, canalization of the Ohio River apparently does not greatly affect the use of this river for water supply and other purposes. On other rivers, such absence of effects is not universal.

122. Future canalization of tributary streams now subject to low summer flows may benefit stream quality by virtue of flow regulation necessary to insure adequate navigation water supply. However, future changes in the quality of Ohio River water, attributable to either new or existing canalization, probably will be minor and of local significance.

123. *Comparison of existing with possible future conditions.*—Population and industrial changes will have a serious effect on the future condition of Ohio River Basin streams. Their effect will be continuous and generally detrimental, and probably will increase in intensity until about 1965, after which time significant changes are not anticipated for a considerable period. Pollution by acid mine drainage is expected to increase indefinitely throughout the area of the bituminous coal fields. On the other hand, low flow control now being provided will have beneficial effects on the sanitary condition of streams. There appear to be no other factors of broad general significance with regard to anticipated conditions of stream sanitation.

124. In general, the detrimental effects of organic pollution of the main Ohio River are estimated to have reached a peak, primarily because the effects of population and industrial growth anticipated for the next quarter century will be offset by discharge regulation now being provided. On the other hand, there is evidence that discharge modification at extremely low stages may increase coliform bacteria counts at specific localities primarily as a result of modification of stream velocities. In consequence, slightly more severe bacterial pollution than now exists may result from population increases anticipated. Local increases in domestic waste concentrations may result from new sewerage construction in existing communities; however, the extent of sewerage service in the larger metropolitan areas is such that only slight increases from this source can be expected in these areas. Unless a mine-sealing program is vigorously prosecuted mine-acid loads will become increasingly heavy in the future, with the result that acid waste concentrations in streams not benefited by low-flow control will increase over present levels, and more severe damage to water users will result than that now experienced. In spite of corrective measures applied to date, the present trend toward increased acidity in the upper Ohio River Basin is such that more than a 50-percent increase in damages from this source may be expected by 1960.

125. All factors considered, the sanitary condition of most streams in the basin appears to be undergoing a slow process of deterioration. The results obtained by the accomplishment of the suggested program of improvement (see ch. X) must therefore be protected by adequate control of all existing, new, and future sources of pollution.

VIII. Objectives of Pollution-Control Activities

126. *Water uses and present adverse effects of pollution.*—The utility of the waters of the Ohio River Basin, and of the country as a whole, is a valuable public asset closely related to public welfare. The objective of the public authorities in the matter of pollution control should be to insure conditions which will permit the best social and economic use of the Nation's watercourses. In determining this use, public opinion must be considered.

127. The most important uses of streams are for domestic, industrial, and agricultural water supplies, waste disposal, navigation, support of fish and aquatic life, recreation, and power production. Pollution-control activities should be directed and correlated with all important stream uses in a manner which will permit realization of the greatest possible yield of public benefit from natural watercourses.

128. In the Ohio River Basin all major streams and numerous small

streams are used for water supply, and practically all streams are used for waste disposal. These uses are basically opposed and, if waste disposal is carried to excess, water supplies suffer proportionately. At the present time it appears that there are obtainable, at most points in the Ohio River Basin, adequate water supplies safe for public consumption after treatment, and capable of serving the needs of agriculture and industry. It does not appear that the adverse effects of waste disposal on water supply will necessarily be intensified in the future. On the other hand, there are some points in the basin, notably on upper reaches of the main stream and at localized points in tributary areas, where the high bacterial content of the streams causes serious concern as to the safety and reliability of treated waters, even after use of the best-known methods of treatment. Acid discharges, mainly to upstream tributaries, and taste-, and odor-producing wastes, also cause damage to water supplies. These latter damages are more readily apparent to the layman than are the dangers of excessive bacterial pollution. Outbreaks of gastroenteritis indicate what can occur when stream conditions are adverse or operation of treatment plants is ineffective.

129. Navigation and hydroelectric power production both suffer to some extent from the wastes now being discharged into the streams of the Ohio River Basin. However, damage to these uses is negligible, except where pollution by acid mine drainage is severe. Acid wastes have been estimated to cause damages to the extent of more than $2,000,000 annually in the area upstream from the point where the Ohio River crosses the western boundary of Pennsylvania. Of this damage more than half is said to be to Federal and private navigation interests. Damage of this magnitude, as well as the adverse effect of acid wastes on water supplies, much of which has not been evaluated because of its intangible nature, indicates that action to reduce acid waste discharges would be in the public interest.

130. It may be said that use of the streams of the Ohio River Basin for waste disposal has progressed to a point where the propriety of using the streams for water sports has disappeared. Swimming and boating are practiced by a small fraction of the population, but cases of typhoid fever and other gastric disturbances are repeatedly traceable to the former activity. There are, of course, still some stream reaches, mainly in headwater areas, where fishing is worth while and where swimming is reasonably safe, but these reaches are in remote and sparsely populated regions which cannot serve readily any considerable portion of the population of the basin.

131. *Physical and economic limitations.*—Physical and economic considerations are such that the complete elimination of wastes from streams is a manifest impossibility. Moreover, unlimited curtailment of the disposal of wastes by dilution would result in a needless sacrifice of the self-purification capacity of streams, which capacity is itself a valuable natural resource. It is obvious that the most effective social and economic use of public waters would not accrue if vital domestic and industrial activities were unduly curtailed by arbitrarily restricting the waste-disposal use of streams for the benefit of desirable uses, such as recreation. A basic consideration in pollution-control activities must be the fact that the waste-disposal use of streams has become an important factor in the economic existence of the people. However, even in the face of this compelling use, it is unlikely that the public welfare has been best served in the Ohio River Basin when numerous

sources of public water supply are dangerously polluted, important tangible damages to other vital water uses can be demonstrated, and aquatic recreational facilities, specifically bathing and fishing, have been virtually destroyed for mass enjoyment.

132. The pollution of streams has been a gradual process, increasing in intensity with domestic and industrial growth, with the result that the attendant technical, financial, and administrative difficulties have frequently been at hand prior to public realization that a serious problem existed. These difficulties have discouraged the planning of a solution of adequate extent. The conclusion seems inescapable that irresponsible dumping of wastes, which has been the general rule in the basin in the past and continues to be the rule in many sections of the basin, has not resulted in the most effective use of the public waters of the Ohio River Valley, and does not accurately reflect present public opinion or desire in the matter of pollution control. In view of this, it appears that public welfare may be served by provision of pollution control works which will permit the maintenance of higher standards of stream quality than now obtain. The most nearly applicable set of standards for a specific stream reach must be established in the light of the uses of the reach, each use being weighted with consideration for its relative importance to public welfare. It should be pointed out, however, that appreciable progress has been made in providing correctives in some parts of the basin. As a matter of fact, if the rate of progress in correction which prevailed during the period 1935–40 were to be resumed after the war, 20 more years would witness completion of the suggested program.

133. Since streams can assimilate a certain amount of pollution without undue adverse effects on their established or desired use, the program for improvement should contemplate the removal of only that part of pollutive substances which the streams cannot assimilate.

134. *Water quality characteristics.*—The behavior of streams subject to pollution, and the quality of the waters therein, have been studied extensively in Europe and in the United States. As a result, desirable characteristics of stream quality pertinent to specific water uses have been gradually established. These characteristics have been described in a preceding report section and are summarized in table 7. They are a good résumé of general experience and, in particular, of exhaustive studies and surveys in the Ohio River Basin. In general, the maintenance of at least the limiting minimum water quality characteristics of table 7 is considered a desirable goal of pollution abatement activities in the Ohio River Basin for localities where the maintenance of these standards will be of benefit to present and probable future water uses.

135. The limiting requirements are as follows:

Coliform bacteria per milliliter:
- Not over 200 in more than 5 percent of samples.
- Monthly average not over 200.

Dissolved oxygen content, parts per million:
- Monthly average not less than 5.0 (see note on table 7).
- Daily average not less than 3.0.

5-day biochemical oxygen demand at 20° C, parts per million: Monthly average not over 5.0.

pH value:
- Not less than 4.0.
- Not more than 9.5.

Phenol content, parts per billion: Not over 10.0.

136. Where present conditions are such that a reasonable degree of pollution control would make recreational use of streams available to large centers of population these standards should be raised.

137. The means of satisfying the outlined requirements, or higher ones where applicable, is the regulation of waste disposal into public waters. Waste-disposal regulation should seek to place the points of waste discharge where they will do the least harm and should seek so to limit the volume and concentration of wastes that damage to public interests at downstream points will be minimized. Proper correlation of water uses with water-quality standards will permit such regulation without serious inroads upon essential waste disposal use of streams. The need for regulatory measures extends to both existing and future sources of pollution.

138. *Summary.*—The objective of pollution control activities is the regulation of waste disposal into public waters, such that standards of water quality may be maintained which are commensurate with stream use in specific localities, to the end that the greatest possible yield of public benefits will accrue.

IX. Attainment of Objectives

139. The difficulties which hamper pollution-abatement activities are technical, financial, and administrative.

140. *Technical difficulties.*—Technical difficulties in pollution abatement are mainly those of industrial waste control. These arise because there are no known satisfactory methods of treatment for some wastes and because other wastes, including acid-mine drainage, require complex treatment; or the methods must be so extensive as to render adequate control extremely tedious and frequently only partially effective. However, most wastes, including both domestic and industrial, are subject to treatment by well-established and not unduly expensive methods. Further research and experimentation with new methods of waste treatment should improve and extend technique to a point where such technical difficulties will no longer be of serious consequence.

141. Designation of a governmental agency to act as a clearing house for information on waste treatment methods and to conduct research where necessary would help to effect an early solution of remaining technical problems. In addition, it would be impractical to undertake full regulation of stream pollution, on as large a scale as Ohio River problems require, without the sound technical background which could be supplied by such a governmental agency.

142. Technical difficulties also result because of practical and economic limitations on the degree of pollution control which can be applied in specific cases. In localities where residual waste concentrations will continue to be excessive in spite of the application of all reasonable corrective measures, controlled waste disposal probably will be the predominant stream use unless the responsible domestic or industrial activity is curtailed. An engineering solution is rendered difficult because many pollution damages and pollution abatement benefits (or damages) are not susceptible to evaluation and, as a result, a satisfactory comparison between the cost of abatement works and anticipated benefits cannot be set forth. However, the situation is not unusual in the construction of public works, and its solution in the United States customarily is to provide, as equitably as possible, all

persons concerned with an opportunity to express their views by direct vote or by public presentation of supporting information. It appears that this portion of the technical pollution-abatement problem must find its solution in an administrative arrangement which will permit the interested public to choose between use of certain streams for controlled waste disposal and curtailed activities.

143. *Financial difficulties.*—Financial difficulties in pollution abatement are mainly those of equitably distributing the cost of abatement works. The first serious difficulty arises from the fact that, with few exceptions, benefits to be obtained by regulation of waste disposal cannot be evaluated with sufficient accuracy to permit a satisfactory economic analysis of specific projects. While it is true that in some industries byproducts of value result from waste regulation and offset a part or all of the cost of regulation, and that in certain localized areas control of specific wastes may be economically justified in terms of benefits to downstream water users, in general the readily evaluated benefits of pollution control works are but a small part of their cost.

144. A second financial difficulty is that sources of pollution, which might reasonably be expected to bear the cost of regulating their own waste disposal, are usually not the recipients of the major portion of the improvements to be realized by such regulation because these improvements most frequently occur at downstream points. While it is true that some communities, considering the benefits worth the costs, have solved purely local pollution problems at their own expense, this has not been a common occurrence in the Ohio River Basin. There are noteworthy cases in which polluters have resisted efforts to regulate their waste disposal on the basis that others alone would benefit from the expenditures required.

145. The effects of the financial difficulties cited are to destroy all cogent economic incentives for polluters to solve their own problems, and to make it difficult for those damaged by stream pollution to obtain relief. While common law recognizes the right of riparian owners to clean streams and it is the right of such owners to sue polluters and collect damages or require abatement of pollution, as heretofore stated, the damages are usually difficult to evaluate and prove and, furthermore, the courts recognize a well-established community or industry as favorable to the public welfare, even though it may be a gross polluter. The result is, more often than not, that such polluters are not disturbed, or are required to pay relatively small damages, neither of which alternatives accomplishes any pollution abatement.

146. Statutory limitation of the bonding and taxing power of many communities has frequently been mentioned as a financial difficulty hampering progress in domestic pollution-abatement activities. However, it is believed that this difficulty is not basic in nature and may readily be overcome at such time as the public desires the expenditure of public funds for pollution abatement.

147. There are several basic considerations which underlie the problem of equitably distributing the cost of pollution abatement works. Among these considerations it may be contended that industries exist only in response to public demand for their products and, therefore, that the public is indirectly responsible for all stream pollution, both industrial and domestic, and ultimately must bear the cost of all pollution-abatement activities, either by direct expenditures or partially by direct expenditures and partially in the form of increased

costs for industrial products. In lieu of expenditures for pollution control, it appears that the public must accept stream pollution or forego the practice of activities, either domestic or industrial, which bring it about.

148. Had the beginnings of waste disposal and waste-disposal regulation been concurrent in the United States, it is probable that each polluter would have borne the cost of his own waste-disposal problems, and that a thoroughly equitable distribution of costs would have resulted. It might be concluded from the foregoing statement that an equitable distribution of costs would result if each polluter was now made to stand the full cost of correcting his own waste discharges. This is not entirely true. Obviously, once established, a community or industry no longer has wide physical latitude with respect to waste disposal. Hence, a reversal of public waste-disposal policy at this late date would work a hardship on communities and industries which located under the present policy without regard to ease of waste-disposal correction if the full cost of indicated abatement works were to be carried by the pollution sources alone.

149. A sound financial policy must recognize these factual situations. It serves no useful purpose arbitrarily to declare that a riparian owner has a right to clean streams above all else, and therefore others must pay to make them clean, because if there has been any benefit to the Nation as a result of the unregulated discharge of wastes which has prevailed, this benefit has been in the form of aid to national expansion and, hence, has benefited all, including riparian owners. On the other hand, where damages occur as a result of stream pollution, a policy which contemplates irresponsible waste discharge is of economic benefit to polluters in an amount at least equal to the cost of providing a minimum of treatment. It is logical to conclude that an equitable distribution of pollution-abatement costs should contemplate their division between the polluter who has a definite responsibility in this connection, and the beneficiaries of improvements resulting from provision of pollution-abatement works. The present status should be reckoned as a starting point and the financial burdens should be apportioned equitably between these entities in proportion to their responsibilities and requirements.

150. The lack of a provable economic basis for providing pollution-abatement works is not likely to be a serious obstacle providing costs are properly apportioned among several interests rather than being concentrated on one interest.

151. Governmental financial aid has been effective in the past in hastening the accomplishment of pollution control. Such aid should hasten completion of a comprehensive program for the Ohio River Basin. However, there are no elements in such a program, with the possible exception of mine sealing and supplemental low flow control, which could not be accomplished without governmental financial aid, providing public demand called for such accomplishment.

152. *Administrative difficulties.*—Administrative difficulties in pollution abatement are the most serious encountered in the Ohio River Basin, mainly because of the interstate character of many of the pollution problems of the area. However, there is no reason to suppose that tributary basin problems confined to a single State cannot be solved by action of the involved State alone, without administrative difficulty.

153. Many of the States of the Ohio River Basin have laws intended to regulate the pollution of their streams. These laws have had varying but not outstanding success. However, they have demonstrated that pollution control within a State can be accomplished by State activities, and it appears that cases of ineffectiveness in State control can be ascribed partly to lack of public demand for effectiveness and lack of public willingness to bear the cost of regulation. Where the effects of pollution have become sufficiently obnoxious to create a strong public demand for correction, it almost invariably has brought about alleviation of the condition. In this connection, it may be stated that as far as is known practically no legislation promulgated by any subdivision of Government has accomplished the intended pollution abatement result unless there has been a public demand for that result.

154. Interstate stream-pollution problems are another matter. The administrative difficulties inherent in their solution have been recognized by many States, some of which have entered into compacts or agreements in an effort to solve these problems.

155. The Potomac Valley Conservancy District was formed by the States of Maryland, West Virginia, Virginia, and Pennsylvania and the District of Columbia, to control the sanitary condition of the Potomac River insofar as it affects the several States. New Jersey, New York, and Connecticut entered into a tri-State compact to control the sanitary condition of the tidal and coastal waters touching the signatory States. An interstate commission on the Delaware River Basin was formed by the States of Delaware, New Jersey, New York, and Pennsylvania, to control the pollution of the Delaware River. The Red River of the North Drainage Basin Commission was formed by the States of Minnesota, North Dakota, and South Dakota, to control the pollution of the Red River of the North. The Ohio River Valley Water Sanitation Compact was drafted by representatives of the States of Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Tennessee, and West Virginia to control the sanitary condition of the Ohio River and its tributaries which are interstate in character. This compact has not been ratified by a sufficient number of States to cause its adoption.

156. While these compacts are intended to secure improvement of interstate waters, they are of doubtful efficacy because they do not avoid the difficulty which has most hampered control heretofore.

157. In part, the Ohio River Compact reads as follows:

> No such order (to wholly or partially discontinue the discharge of wastes) shall go into effect unless and until it receives the assent of at least a majority of the commissioners from each of not less than a majority of the signatory States; and no such order upon a municipality, corporation, person, or entity in any State shall go into effect unless and until it receives the assent of not less than a majority of the commissioners from such State.

It is obvious that under this compact any municipality, corporation, person, or entity in any one State can block action of the commission within that State if it controls a majority of the commissioners (2 out of 3, as now proposed) from the State in which the municipality, corporation, person, or entity resides or conducts its business.

158. A fairly even balance among the interests of the several States is essential to the satisfactory solution of interstate stream-pollution problems by these States. Under present laws and compacts there is no such even mutuality of interests and, hence, the possibility

of solving Ohio River pollution problems by the present interstate compact does not appear good.

159. The following circumstances are believed to contain the elements which are inimical to the solution of interstate pollution problems on the Ohio River.

(*a*) There is no agency either of the Federal Government, or of a combination of the several basin States, which is in a position to administer interstate pollution abatement activities.

(*b*) Due to the lack of such an agency, there is no means of initiating studies and proceedings which affect all of the interests involved in interstate pollution problems.

(*c*) There is no present means of apportioning costs of pollution abatements works between both polluting agencies and interests benefited by pollution abatement.

(*d*) There is no means of securing financial participation of local interests, although this could be accomplished through State governments if other circumstances were propitious.

(*e*) There is no assurance now that local interests will maintain and operate plants constructed for pollution abatement.

(*f*) There is no way at present to insure that unregulated future sources of pollution will not be established which will offset improvements made in existing pollution sources.

(*g*) There is no agency which can coordinate plans and contract arrangements for the construction of pollution abatement works, for the purpose of eventually attaining a complete solution in a manner which will be economical of public funds.

X. Program of Improvement

160. This section presents a comprehensive program of pollution abatement works for the Ohio River Basin. It contemplates control of pollution from all existing and future significant waste sources. The works named in the program would control significant existing pollution. Certain projects are suggested for initial construction. Administrative difficulties being discussed elsewhere, this section covers technical questions only.

161. A means to insure adequate control of pollution from future sources is an essential prerequisite to the success and economy of widespread pollution control activities in the Ohio River Basin. In the absence of such control, regulation at existing sources of pollution will become inadequate in maintaining stream quality.

162. Various means or methods are available to reduce the amount and effect of harmful suspended or dissolved substances before they are permitted to reach the streams. Prominent among these are screening, sedimentation, flocculation with or without chemicals, bacterial action, neutralization, industrial recovery, evaporation, filtration, and disinfection. They may be used singly or in combination depending upon the results to be desired. A primary treatment plant for domestic sewage usually consists of screening and sedimentation and removes about 50 percent of the suspended solids, 35 percent of the biochemical oxygen demand and 25 to 50 percent of the pathogenic (disease causing) bacteria. Chlorination (disinfection) may supplant primary treatment and secure the removal of 90 to 95 percent of the pathogenic bacteria. Additional facilities may be added to a primary plant to increase the degree of treatment. These

additional facilities are collectively known as a secondary treatment plant and the process known as secondary treatment. An activated sludge (bacterial action) plant, rendering secondary treatment and utilizing final sedimentation, filtration, and disinfection, will remove practically all harmful substances and bacteria. A plant in which primary and secondary treatment is combined is generally called a secondary sewage-treatment plant.

163. Many industrial wastes may be collected in municipal sewerage systems but due to the fact that human wastes generally predominate, municipal sewage is known as domestic sewage and treated in plants of the type discussed in paragraph 162. For various reasons other industrial wastes are treated separately. Methods of industrial waste treatment are specialized and vary according to the nature of the industry. They include screening, flocculation, sedimentation, neutralization, industrial recovery, and evaporation. Very often methods similar to those for treating a domestic sewage may be used.

164. The adverse condition of streams in the Ohio River Basin is due to the harmful effects of wastes discharged therein. Industrial waste depletes the natural dissolved oxygen and imparts undesirable acid, alkali, odor, and taste characteristics. Domestic waste depletes the oxygen and contributes harmful bacteria. Mine drainage contributes corrosive sulfuric acid. Domestic waste dominates the sanitary condition of the streams as it contributes practically all of the pathogenic bacteria which are so dangerous to life and health.

165. Survey results indicate (1) that the program for improvement should contemplate the initial construction of primary sewage-treatment plants at all significant sources of pollution from domestic wastes where the quality of water downstream therefrom is adverse to the safe and established use of the stream as a source of water supply, (2) that contributors of industrial wastes located in close proximity to the above significant sources of domestic waste pollution should concurrently provide approximately equivalent treatment to their wastes, and (3) that, if the inhabitants of the basin as a whole are to secure the maximum available benefits for a given expenditure, the program for improvement should include (*a*) the construction of secondary facilities to improve the degree of treatment at some of the sources of pollution discussed in (1) above, (*b*) the construction of secondary facilities at many existing plants, (*c*) the construction of new primary and secondary treatment plants at many other locations and (*d*) the construction of industrial waste treatment facilities throughout the basin giving a degree of treatment approximately equal to that provided in nearby community plants.

166. *Collection and treatment of domestic wastes.*—With the exception of interceptor sewers, collection works for sewage may be considered property improvements, the cost of which should not be charged directly to pollution abatement, although provision of such works prior to provision of sewage treatment facilities is essential. Separate sanitary and storm sewerage systems are favored because of sewage treatment difficulties involved with combined sewers. It has been estimated that the probable cost of additional sewage collection facilities, and modifications in existing facilities, essential to completion of the program of pollution control outlined herein, would be in the neighborhood of $100,000,000, not counting the cost of needed interceptors. Summarized cost estimates for interceptor construction are presented later in this section.

167. The domestic waste treatment measures suggested have been selected after study of the results of field and laboratory surveys. Correlation of data for individual waste sources on the volume and strength of pollutants, discharge characteristics of carrying waterways, downstream water uses, and the self-purification capacity of the involved streams, with the findings of the laboratory survey, permitted determination of the degree of sewage treatment required to provide satisfactory stream conditions insofar as this is possible. However, nothing less than primary treatment, embodying at least screening and plain sedimentation and necessary interceptor construction, has been contemplated for the waste sources for which treatment cost estimates are contained herein. All significant sources of domestic wastes, including metropolitan areas and individual communities having 500 or more inhabitants were investigated in this manner, including those where treatment is now provided. Summarized cost estimates for community pollution control measures are presented later in this section.

168. *Collection and treatment of industrial wastes.*—Control of pollution resulting from industrial wastes in the Ohio River Basin has several major aspects, namely:

(*a*) Collection of wastes for discharge to municipal treatment plants, or

(*b*) Treatment of wastes by industries, prior to discharge to streams, or pretreatment prior to discharge to municipal treatment plants, and

(*c*) Modification of plant methods and procedures.

169. The cost of collecting wastes, and in a few cases of modifying methods and procedures within individual industrial establishments, is not included in estimates of the cost of the pollution-abatement program. However, where applicable, the estimated cost of connecting existing industrial waste sources to municipal sewer systems has been included.

170. Selection of the industrial waste control measures suggested has been based upon studies of all significant waste sources, similar to the studies of domestic waste sources, and summarized cost estimates for industrial pollution control measures are presented later in this section. In general, when applicable, a minimum of industrial waste treatment equivalent in effect to primary sewage treatment has been contemplated. Cost estimates also are included in certain cases for the control of inorganic industrial pollutants.

171. *Control of acid mine drainage.*—Control of pollution by acid mine drainage requires continuance of the present mine sealing program. Cost estimates are included for an initial program wherein unit sealing costs are to be limited to a maximum of $10 per ton year of acid producing capacity sealed and to mine areas not connected to active ventilating systems. In order to expedite the sealing of future sources of acid mine wastes, it is suggested that an effort be made to correlate state mining laws to the end that mining procedure may be adopted which will be favorable to mine sealing operations.

172. *Low-flow control.*—Provision of low-flow control in the Allegheny and Monongahela River Basins is required to permit full realization of the benefits of mine sealing. It will add to the beneficial effects of other waste control measures. Low-flow control may be satisfactorily and most economically accomplished as an incidental feature of the operation of reservoirs provided primarily for other

purposes, such as flood control and the production of hydroelectric energy. Under such circumstances, low-flow control may be obtained at comparatively slight cost. On the other hand, provision of reservoir capacity for the sole purpose of flow regulation is not economically feasible at this time. Because advantageous development of the water resources of the Ohio River Basin usually contemplates provision of low-flow control as a low-cost incidental reservoir function, rather than as a primary reservoir function, and because its provision is largely dependent on the need for flood control and power storage, cost estimates for such facilities have not been included herein. If storage capacity is provided in the Allegheny and Monongahela River Basins for low-flow control only, and in the quantity indicated as being best as a supplement to other methods of pollution abatement, the first cost would be about $20,000,000.

173. *Physical aspects and estimated cost of the pollution-control program.*—Tables 12 and 13, herewith, present pertinent physical aspects and cost estimates for the outlined pollution-control program for the Ohio River Basin. The program is set up without regard for possible sources of funds for its prosecution. The basis of the program is that every damaging source of pollution is now susceptible to some degree of abatement. It contemplates corrective measures at all existing significant pollution sources. Summarized cost estimates for these are included. Estimates of the cost of controlling future sources of pollution are not included, for obvious reasons.

TABLE 12.—*Physical aspects of suggested program of pollution control, Ohio River Basin*

Basin	Drainage area (square miles)	Population, 1940 census	Suggested program of pollution control — Municipal treatment — Number of plants				Population involved — Primary			Population involved — Secondary		
			Primary	Secondary	Improvements	Total	Now sewered	1940 census	Design	Now sewered	1940 census	Design
Allegheny River	11, 730	1, 236, 694	86	7	7	100	[1] 654, 300	863, 400	586, 500	57, 900	58, 600	70, 400
Monongahela River	7, 380	1, 264, 674	66	16	1	83	[1] 683, 400	764, 100	476, 500	92, 800	102, 300	105, 000
Beaver River	3, 145	728, 368	14	5	8	27	293, 300	295, 000	361, 900	3, 800	5, 700	7, 700
Muskingum River	8, 040	812, 028	23	20	9	52	88, 200	106, 900	124, 000	48, 400	61, 000	72, 500
Little Kanawha River	2, 320	92, 355	6	0	2	8	5, 300	5, 500	5, 900	0	0	0
Hocking River	1, 185	113, 555	5	2	1	8	21, 000	25, 300	33, 100	2, 400	2, 500	3, 600
Kanawha River	12, 300	834, 845	35	16	6	57	131, 900	141, 200	179, 900	32, 500	42, 800	52 600
Guyandot River	1, 670	148, 257	13	0	0	13	19, 700	23, 800	27, 700	0	0	0
Big Sandy River	4, 280	411, 905	20	2	0	22	36, 600	51, 000	57, 000	7, 000	7, 700	9, 000
Scioto River	6, 510	739, 551	18	4	8	30	4, 600	12, 800	16, 900	6, 500	11, 500	13, 000
Little Miami River	1, 755	135, 474	3	8	3	14	2, 900	5, 000	5, 500	4, 200	6, 000	6, 800
Licking River	3, 670	[2] 170, 143	2	11	1	14	1, 200	2, 500	2 800	12, 800	20, 100	23, 800
Miami River	5, 385	830, 481	7	18	7	32	99, 200	100, 000	108, 700	28, 000	39, 000	50, 300
Kentucky River	6, 940	481, 969	3	7	3	13	18, 200	20, 000	24, 300	17, 500	20, 800	23, 300
Salt River	2, 890	139, 868	0	7	1	8	0	0	0	3, 200	6, 000	7, 200
Green River	9, 220	444, 392	9	7	7	23	3, 200	7, 900	11, 200	7, 700	15, 400	17, 200
Wabash River	33, 100	2, 508, 598	30	132	24	186	142, 800	212, 900	314, 000	149, 800	257, 100	318, 300
Cumberland River	18, 000	1, 129, 002	13	18	3	34	134, 700	202, 000	283, 500	37, 300	58, 000	62, 100
Tennessee River	40, 600	2, 491, 298	64	37	9	110	373, 400	491, 000	670, 900	116, 000	161, 500	183, 700
Minor tributaries	23, 780	1, 385, 292	17	23	5	45	[1] 73, 600	45, 400	50, 300	22, 800	39, 800	45, 000
Ohio River direct		[2] 2, 717, 187	111	0	0	111	2, 018, 500	2, 170, 000	4, 253, 700	0	0	0
Total	203, 900	18, 815, 846	545	340	105	990	4, 806, 000	5, 545, 700	7, 594, 300	650, 600	915, 800	1, 071, 500

Basin	Suggested program of pollution control							
	Municipal treatment				Interceptor construction required	Independent industrial waste correction required	Mine acid load economical to remove for average cost of $10 per ton-year, in tons per year	Remarks
	Population involved							
	Improvements		Total					
	Now connected	1940 census	Now sewered or connected	1940 census				
Allegheny River	79,600	77,300	[1] 791,800	999,300	Yes	Yes	164,960	Low flow control suggested.
Monongahela River	25,000	21,800	[1] 801,200	888,200	Yes	Yes	198,680	Additional low flow control suggested.
Beaver River	82,600	85,400	379,700	386,100	Yes	Yes	6,500	Do.
Muskingum River	180,300	185,000	316,900	352,900	Yes	Yes	[3] 19,000	
Little Kanawha River	4,800	5,000	10,100	10,500	Yes	No	50	
Hocking River	1,100	1,200	21,500	29,000	Yes	No	(3)	
Kanawha River	11,200	12,000	175,600	196,000	Yes	Yes	2,170	
Guyandot River	0	0	19,700	23,800	Yes	No	1,330	
Big Sandy River	0	0	43,600	58,700	Yes	No	18,320	
Scioto River	19,800	27,100	30,900	51,400	Yes	Yes	7,100	Low flow control suggested.
Little Miami River	19,100	20,500	26,200	31,500	Yes	Yes		
Licking River	6,300	9,000	20,300	31,600	Yes	Yes		
Miami River	71,000	86,700	198,200	225,700	Yes	Yes		
Kentucky River	47,700	51,700	83,400	92,500	Yes	Yes	9,520	
Salt River	1,700	4,700	4,900	10,700	Yes	Yes		
Green River	18,700	25,000	29,600	48,300	Yes	No	23,140	
Wabash River	495,200	544,500	787,800	1,014,500	Yes	Yes	30,403	
Cumberland River	6,500	9,400	178,500	269,400	Yes	Yes	93,070	
Tennessee River	20,700	29,000	510,100	681,500	Yes	Yes	10,770	
Minor tributaries	3,900	7,400	[1] 100,300	92,600	Yes	Yes	[4] 77,756	
Ohio River direct	0	0	2,018,500	2,170,000	Yes	Yes		Additional low flow control suggested.
Total	1,095,200	1,202,700	6,551,800	7,664,200	All basins	No..5 basins Yes 16 basins	662,769	Low flow control of value in all basins.

[1] Includes some population to be served in Ohio River plants.
[2] Population of Covington-Newport area is included under "Ohio River direct".
[3] Muskingum and Hocking Rivers shown together.
[4] Includes 11,070 tons per year from unclassified mines in Virginia.

TABLE 13.—*Economic aspects of suggested program of pollution control,*[1] *Ohio River Basin*

Basin	Drainage area, square miles	Population (1940 census)	Estimated cost of suggested program of pollution control (dollars)								
			Estimated capital cost								
			Municipal treatment				Inter-ceptors	Independent industrial treatment, pretreatment connections, etc.	Mine seal-ing	Total	
			Primary	Secondary	Improve-ments	Total				By basins	Per capita [3]
Allegheny River	11, 730	1, 236, 694	5, 070, 000	890, 000	390, 000	6, 350, 000	3, 670, 000	660, 000	1, 460, 000	12, 140, 000	9. 80
Monongahela River	7, 380	1, 264, 674	4, 710, 000	1, 480, 000	80, 000	6, 270, 000	5, 870, 000	1, 110, 000	1, 600, 000	14, 850, 000	11. 70
Beaver River	3, 145	728, 368	2, 660, 000	160, 000	150, 000	2, 970, 000	1, 990, 000	1, 040, 000	50, 000	6, 050, 000	8. 30
Muskingum River	8, 040	812, 028	1, 100, 000	1, 160, 000	390, 000	2, 650, 000	2, 220, 000	310, 000	[3] 110, 000	5, 290, 000	6. 50
Little Kanawha River	2, 320	92, 355	85, 000	0	5, 000	90, 000	120, 000	0	0	210, 000	2. 30
Hocking River	1, 185	113, 555	305, 000	70, 000	5, 000	380, 000	240, 000	0	(3)	620, 000	5. 50
Kanawha River	12, 300	834, 835	1, 520, 000	860, 000	90, 000	2, 470, 000	2, 530, 000	1, 270, 000	120, 000	6, 390, 000	7. 70
Guyandot River	1, 670	148, 257	300, 000	0	0	300, 000	230, 000	0	10, 000	540, 000	3. 60
Big Sandy River	4, 280	411, 905	610, 000	130, 000	0	740, 000	500, 000	0	240, 000	1, 480, 000	3. 60
Scioto River	6, 510	739, 551	240, 000	200, 000	230, 000	670, 000	260, 000	370, 000	40, 000	1, 340, 000	1. 80
Little Miami River	1, 755	135, 474	70, 000	230, 000	110, 000	410, 000	120, 000	50, 000	0	580, 000	4. 30
Licking River	3, 670	170, 143	40, 000	420, 000	60, 000	520, 000	180, 000	10, 000	0	710, 000	4. 20
Miami River	5, 385	830, 481	820, 000	820, 000	480, 000	2, 120, 000	1, 560, 000	1, 180, 000	0	4, 860, 000	5. 90
Kentucky River	6, 940	481, 969	210, 000	370, 000	90, 000	670, 000	460, 000	360, 000	130, 000	1, 620, 000	3. 40
Salt River	2, 890	139, 868	0	140, 000	60, 000	200, 000	10, 000	250, 000	0	460, 000	3. 30
Green River	9, 220	444, 392	150, 000	290, 000	160, 000	600, 000	180, 000	0	310, 000	1, 090, 000	2. 50
Wabash River	33, 100	2, 508, 598	2, 130, 000	5, 310, 000	1, 430, 000	8, 870, 000	3, 960, 000	1, 690, 000	80, 000	14, 600, 000	5. 80
Cumberland River	18, 000	1, 129, 002	1, 280, 000	970, 000	80, 000	2, 330, 000	4, 540, 000	270, 000	780, 000	7, 920, 000	7. 00
Tennessee River	40, 600	2, 491, 298	4, 650, 000	2, 580, 000	190, 000	7, 420, 000	15, 450, 000	1, 610, 000	100, 000	24, 580, 000	9. 90
Minor tributaries	23, 780	1, 385, 202	520, 000	830, 000	70, 000	1, 420, 000	890, 000	280, 000	480, 000	3, 070, 000	2. 20
Ohio River direct		2, 717, 187	27, 560, 000	0	0	27, 560, 000	40, 350, 000	3, 120, 000	0	71, 030, 000	26. 10
Total	203, 900	18, 815, 846	54, 030, 000	16, 910, 000	4, 070, 000	75, 010, 000	85, 330, 000	13, 580, 000	5, 510, 000	179, 430, 000	9. 50

Basin	Estimated cost of suggested program of pollution control (dollars)										
	Estimated annual cost										
	Operation and maintenance					Amortization and interest					Total estimated annual cost
	Municipal treatment	Interceptors	Independent industrial treatment, pretreatment connections, etc.	Mine sealing	Total	Municipal treatment	Interceptors	Independent industrial treatment, pretreatment connections, etc.	Mine sealing	Total	
Allegheny River	305, 000	Negligible	140, 000	158, 000	603, 000	450, 000	170, 000	90, 000	61, 000	771, 000	1, 374, 000
Monongahela River	270, 000	do	320, 000	173, 000	763, 000	410, 000	275, 000	150, 000	67, 000	932, 000	1, 695, 000
Beaver River	190, 000	do	235, 000	6, 000	431, 000	210, 000	95, 000	135, 000	2, 000	442, 000	873, 000
Muskingum River	105, 000	do	100, 000	[3] 11, 000	216, 000	185, 000	105, 000	40, 000	[3] 5, 000	335, 000	551, 000
Little Kanawha River	5, 000	do	0	0	5, 000	6, 000	5, 000	0	0	11, 000	16, 000
Hocking River	17, 000	do	0	([3])	17, 000	27, 000	11, 000	0	([3])	38, 000	55, 000
Kanawha River	115, 000	do	240, 000	13, 000	368, 000	175, 000	120, 000	165, 000	5, 000	465, 000	833, 000
Guyandot River	15, 000	do	0	1, 000	16, 000	20, 000	10, 000	0	1, 000	31, 000	47, 000
Big Sandy River	35, 000	do	0	26, 000	61, 000	50, 000	25, 000	0	10, 000	85, 000	146, 000
Scioto River	30, 000	do	40, 000	4, 000	74, 000	50, 000	10, 000	50, 000	2, 000	112, 000	186, 000
Little Miami River	16, 000	do	4, 000	0	20, 000	29, 000	5, 000	6, 000	0	40, 000	60, 000
Licking River	24, 000	do	1, 000	0	25, 000	36, 000	8, 000	1, 000	0	45, 000	70, 000
Miami River	95, 000	do	185, 000	0	280, 000	150, 000	75, 000	155, 000	0	380, 000	660, 000
Kentucky River	30, 000	do	5, 000	14, 000	49, 000	45, 000	25, 000	55, 000	5, 000	130, 000	179, 000
Salt River	10, 000	do	4, 000	0	14, 000	14, 000	1, 000	41, 000	0	56, 000	70, 000
Green River	30, 000	do	0	33, 000	63, 000	40, 000	10, 000	0	13, 000	63, 000	126, 000
Wabash River	375, 000	do	250, 000	9, 000	634, 000	625, 000	185, 000	220, 000	3, 000	1, 033, 000	1, 667, 000
Cumberland River	135, 000	do	15, 000	84, 000	234, 000	165, 000	215, 000	35, 000	33, 000	448, 000	682, 000
Tennessee River	395, 000	do	190, 000	11, 000	596, 000	520, 000	725, 000	205, 000	4, 000	1, 454, 000	2, 050, 000
Minor tributaries	70, 000	do	40, 000	52, 000	162, 000	100, 000	40, 000	35, 000	20, 000	195, 000	357, 000
Ohio River direct	1, 765, 000	do	705, 000	0	2, 470, 000	1, 940, 000	1, 890, 000	410, 000	0	4, 240, 000	6, 710, 000
Total	4, 032, 000	do	2, 474, 000	595, 000	7, 101, 000	5, 277, 000	4, 005, 000	1, 793, 000	231, 000	11, 306, 000	18, 407, 000

[1] The cost of providing sewerage facilities would be in the magnitude of $100,000,000.
[2] Based on total population.
[3] Muskingum and Hocking Rivers shown together.

174. The portion of the program devoted to existing waste sources contemplates provision of 545 new primary and 340 new secondary sewage-treatment plants, improvement of existing sewage-treatment facilities at 105 localities, interceptor sewer construction, mine sealing, and independent industrial waste correction where needed. A total of approximately 6,551,800 persons are now serviced by sewers in the affected places, and the 1940 population involved is 7,664,200. Accomplishment of the program would of necessity be a gradual process.

175. Cost estimates in table 13 are based on a review of cost experience in the eastern United States during recent years. Separate estimates were made for each correction suggested but, in general, these were not based on detailed engineering surveys. Thus, individual estimates are subject to error, but the summarized estimates shown are considered to be a good indication of the probable cost of accomplishing the suggested program at mid-1942 prices.

176. Annual costs were computed on the basis of amortization periods of 40 years for interceptors, 20 years for municipal treatment plants, and 10 years or less for independent industrial waste corrections. The interest rate used is 3½ percent for municipal construction, and 5 percent for industrial construction. Annual costs for interceptors and sewage-treatment plants were computed at the lower interest rate.

177. The cost of controlling pollution, including provisions of interceptor sewers, but exclusive of community sewerage systems, is estimated to be $179,430,000. This includes a 15-percent allowance for engineering and contingencies. Annual charges are estimated at $18,407,000 (table 13), or about $1 per capita when distributed over the total population of the basin. However, it should be noted that "total population" includes the population of communities which have already provided treatment. Costs are distributed as follows:

Municipal treatment	$75, 010, 000
Interceptors	85, 330, 000
Subtotal	160, 340, 000
Independent industrial treatment	13, 580, 000
Mine sealing	5, 510, 000
Subtotal	19, 090, 000
Total	179, 430, 000

Annual charges are distributed as follows:

Municipal treatment	$9, 309, 000
Interceptors	4, 005, 000
Subtotal	13, 314, 000
Independent industrial treatment	4, 267, 000
Mine sealing	826, 000
Subtotal	5, 093, 000
Total	18, 407, 000

178. Per capita annual charges for the first two items in the foregoing tabulation (municipal treatment facilities and interceptor sewers) average $1.70 for the entire basin, based on the present population of communities to be served.

179. Estimated per capita costs range from $0.90 in the Allegheny River Basin to $2.60 in areas immediately adjacent to the Ohio River.

The following factors are of importance in determining these costs: the extent and distribution of community development in the various sub-basins; stream-discharge characteristics; industrial waste loads to be treated with community wastes; and predominant stream uses. In general, sewage treatment facilities may be provided for per capita costs in rough inverse proportion to community size. However, in large communities, interceptor construction is frequently expensive, and treatment plant sites difficult to find, resulting in increased unit costs which offset the savings otherwise inherent in large plants.

180. The estimated cost of the facilities at Pittsburgh, Cincinnati, and Louisville is $42,580,000, being 60 percent of the cost of contemplated facilities along the main stream, and 27 percent of those in the entire watershed. If all of the Pittsburgh metropolitan area were regarded as a main stream community the total estimated cost for the Pittsburgh, Cincinnati, and Louisville areas would be $60,900,000, distributed as follows:

Pittsburgh (metropolitan area)	$35, 900, 000
Cincinnati	19, 000, 000
Louisville	6, 000, 000
Total	60, 900, 000

181. The mine-sealing program outlined could be provided for an estimated annual cost of $826,000 (operation and maintenance, $595,000; amortization and interest, $231,000; table 13) or about $0.04 per capita when distributed over the present total population of the Ohio River Basin (18,816,000, 1940 census) or about 4 mills per ton of coal produced. Maximum annual per capita charges, based on total subbasin populations, would be experienced in the Allegheny and Monongahela River Basins, and have been estimated as $0.18 and $0.19, respectively.

182. The estimated cost of the outlined program for independent industrial waste treatment, if borne by the general public, would approximate $0.23 per capita per year based on the total population of the basin. Estimated costs for individual basins would vary from zero to $0.51 per capita per year, depending on the volume, extent, and type of industrial activities involved.

183. If it is assumed that the public eventually must bear the cost of waste control measures, either directly or indirectly, the previously mentioned average annual per capita cost of $1 may be considered applicable. The distribution of expenditure would be as follows:

Municipal treatment	$0. 73
Industrial treatment	. 23
Mine sealing	. 04
Total	1. 00

These figures must be used with great caution because they are based on "total population," which includes the population of communities which have already provided treatment.

184. *Probable accomplishments of the pollution-control program.*—The program of pollution control outlined in this report section would materially improve the streams of the Ohio River Basin for all important water uses. Anticipated results may be classified as "satisfactory control" and "limited control." In general, "satisfactory control" would result in maintenance of "desirable" standards of stream quality (see table 7) commensurate with water use, while "limited control" would result in partial amelioration of present

objectionable conditions commensurate with the technical limitations of waste treatment methods and with the needs of the people in other directions.

185. The program would reduce bacterial pollution sufficiently to insure the safety of efficiently treated community water supplies from surface sources. In general, satisfactory control would result, and average coliform bacteria densities would not in any month exceed 50 per milliliter at water supply intakes. Taste and odor troubles resulting from industrial waste pollution and hardness and acidity resulting from acid mine drainage would be materially reduced.

186. Industrial water supplies and navigation and water power use of streams would be improved by the program, largely as a result of mine sealing. The degree of control would vary from "limited" to "satisfactory," and major benefits would accrue in the upper tributary areas of the Ohio River Basin. Improvement of limited extent would occur in the lower Monongahela River where monthly average acidities as great as 33 parts per million have been observed. It is anticipated that the outlined program would reduce peak monthly average acidities, by 19 parts per million, to about 14 parts per million in this reach.

187. In general, agricultural water supplies would be made suitable, or improved, for stock-watering purposes. Satisfactory improvement would not be universal because of such exceptions as small tributaries locally polluted with mine acids.

188. Recreational facilities would be benefited by the program largely as a result of the control of bacterial and acid pollution. The safety of waters now used in an organized manner for swimming would be insured, subject to reasonable local inspection and regulation. Limited improvement would result in other stream reaches. Fish life would be protected and, in many instances, restored. An improvement of the latter type is anticipated on the lower Allegheny River.

189. The program would also improve general sanitary conditions and, with few exceptions, would result in the maintenance of "desirable" characteristics of stream quality in this respect.

190. The first step in the foregoing plan should be directed toward the control of pollution at those communities whose wastes adversely and dangerously affect public sources of water supply.

191. About 30 sources of water supply, taken from the Ohio River proper and serving about 1,660,000 people are endangered by the disposal of wastes to the stream. Listed below are those main river locations where treatment of wastes is necessary to adequately protect water supplies of downstream communities. While grouped in order and extent of pollutive effects, all locations are considered of equal importance in the initial program for abatement:

Group 1:
- **Huntington, W. Va.**
- **Catlettsburg, Ky.**
- **Ashland, Ky.**
- **Ironton, Ohio.**

Group 2:
- **Pittsburgh, Pa. (Allegheny County area).**
- **Ambridge, Pa.**
- **Aliquippa, Pa.**
- **East Liverpool, Ohio.**

Group 3:
- **Portsmouth, Ohio.**
- **Weirton, W. Va.**
- **Steubenville, Ohio.**
- **Owensboro, Ky.**

Group 4:
- **Cincinnati, Ohio.**
- **Louisville, Ky.**

Group 5:
- **Wheeling, W. Va.**
- **Evansville, Ind.**
- **Parkersburg, W. Va.**

192. Pollution abatement in the areas listed in group 1 is necessary if the raw public water supplies in the Huntington to Portsmouth reach of the Ohio River are to be brought up to the standards fixed by modern sanitary engineering. The work suggested in groups 2 and 3 is also essential, because of present excessive bacterial pollution of raw public water supplies. Group 4 communities discharge wastes in sufficient volume to fix the sanitary condition of relatively long stream reaches. Hence, improvement is also necessary at these points. Group 5 communities are situated so as to fix the sanitary condition of comparatively long stream reaches, although they do not effect such severe downstream damages as does pollution from areas of the foregoing groups. Improvements in group 5 seem required in any comprehensive plan for improvement of the main stream.

193. A program of mine sealing, as outlined herein, should parallel the foregoing improvements.

194. It should not be implied that tributary basin pollution problems should wait for solution on abatement progress on the main stream nor, on the other hand, should the converse be true. However, while tributary problems in many instances are severe, their extent is usually localized and populations damaged are usually small. Severe tributary problems include the following:

Johnsonburg-St. Marys-Ridgway area, Clarion River, Pa.
Youngstown District, Mahoning River, Ohio.
Canton-Barberton-Massillon area, Tuscarawas River, Ohio.
Charleston District, Kanawah River, W. Va.
Columbus-Chillicothe reach, Scioto River, Ohio.
Dayton-Hamilton reach, Miami River, Ohio.
Terre Haute, Wabash River, Ind.
Muncie-Anderson-Indianapolis reach, West Fork White River, Ind.
Nashville District, Cumberland River, Tenn.
Canton District, Pigeon River, Tenn.

195. Listed below are those locations along the tributaries where waste treatment is necessary to protect the water supplies of one or more downstream communities. While the pollutive effects are not as extensive as those of communities on the main river, treatment facilities are just as essential and should be included in the first step of the program:

Girard, Ohio.
Niles, Ohio.
Sidney, Ohio.
Warren, Ohio.
Youngstown area, Ohio.
Chattanooga, Tenn.
Knoxville, Tenn.
Nashville, Tenn.
Charleston Area, W. Va.
Elkins, W. Va.

Industries at Canton, N. C., and Johnsonburg, Pa., contribute severe pollution from pulp and paper mills which adversely affects water supplies. Corrective measures should be taken just as soon as reasonable methods of treatment are available.

XI. Conclusions

196. Practically all streams in the Ohio River Basin are polluted by domestic and industrial wastes while some have severe corrosive characteristics imparted to them by acid mine drainage. The degree of pollution varies from gross nuisance conditions and menace to life and health to conditions adverse to special uses of the streams such as swimming. A program of improvement has been developed from

the survey which is considered essential and justifiable. The improvement, if completed, will secure conditions more suitable and safe for the many uses imposed on the streams.

A. MAIN OHIO RIVER

197. The Ohio River proper is polluted to such an extent that 30 sources of public water supply, serving about 1,660,000 people, are endangered. The threat to life and health is real as even now the coliform bacteria counts often exceed that considered safe for a source of water supply even though treated in a modern plant. The escape of certain disease-causing bacteria, viruses or substances from the water-treatment process, or the slightest failure in the process itself, may result in a serious epidemic.

198. Findings indicate that sufficient control and abatement of pollution should be undertaken to protect properly these sources of water supply. This protection, as well as the attendant improvement of the general sanitary conditions of the Ohio River, more than justifies the cost of the necessary abatement program. The minimum degree and extent of treatment necessary to secure the desired protection consists of the removal of approximately 50 percent of the suspended solids and 35 percent of the biochemical oxygen demand from all sewage entering the river from significant sources, with chlorination of these effluents where further reduction of the bacterial content is necessary for the protection of water supplies. It is therefore essential:

(*a*) That primary sewage treatment plants, with chlorination where necessary and the necessary interceptors, be constructed at the following cities and adjacent metropolitan areas:

Evansville, Ind.
Ashland, Ky.
Catlettsburg, Ky.
Louisville, Ky.
Owensboro, Ky.
Cincinnati, Ohio.
East Liverpool, Ohio.
Ironton, Ohio.
Portsmouth, Ohio.
Steubenville, Ohio.
Aliquippa, Pa.
Ambridge, Pa.
Pittsburgh, Pa.
Huntington, W. Va.
Parkersburg, W. Va.
Weirton, W. Va.
Wheeling, W. Va.

(*b*) That the wastes of industrial plants located within the limits of the above-named cities and metropolitan areas, which cannot be accommodated in the municipal treatment works, be treated to a degree comparable to that provided by the cities.

(*c*) That extensive study and research be given to those industrial wastes now difficult to treat in order to find practical methods of recovery or of treatment at reasonable costs.

B. OHIO RIVER TRIBUTARIES

199. The pollution of a number of the tributaries is as severe or even more severe than the worst reaches on the main Ohio River. The effect of such pollution, however, is for the most part local and has little importance on the Ohio River proper. Certain established water supplies are endangered and corrective measures, similar to those

necessary for the cities and industries on the Ohio River proper, should be undertaken at the following cities and adjacent metropolitan areas:

Girard, Ohio.	Chattanooga, Tenn.
Niles, Ohio.	Knoxville, Tenn.
Sidney, Ohio.	Nashville, Tenn.
Warren, Ohio.	Charleston, W. Va.
Youngstown, Ohio.	Elkins, W. Va.

Industries on the Pigeon River at Canton, N. C., and on the Clarion River at Johnsonburg, Pa., contribute severe pollution from pulp and paper mills. Continued intensive research directed toward the development of better disposal methods is essential if those streams are to be restored to better condition. Abatement of pollution at those two locations is not included as an initial objective.

C. ACID MINE DRAINAGE

200. All streams throughout the coal regions of the Ohio River Basin are badly polluted by acid mine drainage. Sealing of abandoned mines has reduced the amount of acid reaching the streams and has demonstrated the efficacy of mine sealing in the control of acid pollution. However, the measurable annual damage from corrosion and injury to water supplies, as of 1940, to users of the Ohio River and its tributaries above the Ohio-West Virginia-Pennsylvania State line, was over $2,000,000 and probably exceeded $3,000,000 for the entire basin. The intangible damages are probably equal to the tangible damages.

201. Since mine sealing does not eliminate all acid reaching the streams from the mines, low flow control is desirable for dilution of the acid during relatively dry periods. Low flow control may be secured from many existing reservoirs and should be considered in all new reservoir projects. A combined program of limited mine sealing and low flow control will reduce the acid damage by about 55 percent. It will cost approximately $15,000,000 to complete the mine sealing program, of which $5,500,000 will be required for the first step consisting of a limited program (1940 restrictions) to be applied to mines or mine areas where costs will not exceed $10 per annual ton of acid now produced and to areas which were not connected to active ventilating systems (in 1938). In addition, an annual expenditure of $1,000,000 will be required to inspect and maintain all existing and new seals under the outlined first step in the program. Experience and results will govern future steps in the program. This work should be accomplished under the supervision of the United States Bureau of Mines.

D. GENERAL

202. A program meeting the above requirements is the minimum necessary to correct serious and dangerous stream conditions. Such a program will not result in a water quality suitable for the many possible uses of the streams. Specifically, it does not assure satisfactory conditions for the propagation and support of aquatic life or for recreation.

203. A complete, well-balanced program, yielding maximum benefits obtainable at reasonable and justifiable costs, will involve an expenditure of approximately $200,000,000, exclusive of the cost of

certain prerequisite sewerage facilities. Such a program will improve the water quality of nearly all streams in the basin. Many stream reaches will be made suitable or more suitable for the support of fish life and recreational purposes.

204. Except for commerce and navigation, the selection and establishment of stream uses and the enforcement of antipollution measures to secure and maintain a water quality suitable for such uses appear to be proper functions of the States. While the Federal Government has a decided interest in the protection of public health and in wildlife conservation, as well as in the protection and development of commerce and navigation, it is believed advisable that no definite action toward the enforcement of pollution abatement should be undertaken by the Federal Government unless all State and interstate action fails to secure the proper control. The proposed Ohio River Valley water sanitation compact, if modified and vitalized, would provide an improved means for uniform and effective control of all pollution interstate in its effect. Individual States cooperating with the Ohio River Valley Water Sanitation Commission should be able to control uniformly and effectively all pollution intrastate in its effect.

205. The principal obstacle to the abatement of pollution is the actual financing of the necessary facilities. The polluters, the State, and the Federal Government have a direct concern and interest in the effect of the discharge or deposit of organic and inorganic substances, acids, and dangerous disease-causing bacteria or viruses into all bodies of water. Active support and participation on the part of the States and the Federal Government are indicated and needed as a stimulus if any large and comprehensive program for the abatement of pollution is to be undertaken and properly completed in the Ohio River Basin. A comprehensive program of research and education is also needed to discover new and more economical methods of waste treatment and recovery and to inform the public of the necessity for the abatement of pollution.

206. The tangible and intangible benefits accruing to the Federal Government in protecting health and general welfare in the Ohio River Basin, as well as benefits accruing in the reduction of damage to commerce and navigation and the general security obtained by the control of pollution, justify Federal financial aid. This aid should be in the form of grants (say 35 percent of the construction cost of abatement projects) and loans to States, their political subdivisions or municipalities.

XII. Recommendations

A. PROGRAM OF REMEDIAL MEASURES

207. In view of the many factors involved, it is recommended that the Federal Government participate, as hereinafter set forth, in the following program for abatement of pollution on the Ohio River Basin, at an estimated total construction cost of approximately $200,000,000. Units of this program, in order of importance, follow:

(*a*) Construction, at the earliest practicable date, of (1) primary treatment facilities for domestic sewage, including chlorination where necessary, by all communities located within the 27 metropolitan

areas listed below and (2) industrial waste-treatment facilities, rendering a degree of treatment equivalent to that provided by the communities, by all industries located within the same areas whose wastes cannot be handled by community facilities:

Evansville, Ind.
Ashland, Ky.
Catlettsburg, Ky.
Louisville, Ky.
Owensboro, Ky.
Cincinnati, Ohio.
East Liverpool, Ohio
Girard, Ohio
Ironton, Ohio
Niles, Ohio
Portsmouth, Ohio
Sidney, Ohio
Steubenville, Ohio
Warren, Ohio
Youngstown, Ohio, area.
Aliquippa, Pa.
Ambridge, Pa.
Pittsburgh, Pa.
Chattanooga, Tenn.
Knoxville, Tenn.
Nashville, Tenn.
Charleston, W. Va., area
Elkins, W. Va.
Huntington, W. Va.
Parkersburg, W. Va.
Weirton, W. Va.
Wheeling, W. Va.

(*b*) Reduction of acidity in the streams by—

(1) Completing the present limited (1940 restrictions) mine-sealing program, at an estimated cost of approximately $5,500,000, and by providing for inspection and maintenance of all existing and newly constructed seals.

(2) Securing low flow control as far as practical from existing reservoirs and studying the possibility of including low flow control for the dilution of acid and organic pollution in future reservoirs.

(3) Conducting investigations to discover ways and means for economically preventing acid mine drainage, uncontrolled by the limited program, from reaching streams.

(*c*) Construction of all additional treatment plants and facilities as may be found necessary to complete the entire program of improvement. This additional work should be completed within a period of 15 years.

B. STATE COOPERATION

208. In order that effective centralized control of existing and future sources of pollution within the Ohio River Basin may be secured and that the entire program outlined may be properly administered, full cooperation of the States is required. It is therefore recommended:

(*a*) That the Ohio River Valley Water Sanitation Compact be amended to give the three commissioners representing the United States Government voting power equal to that of the commissioners representing the States.

(*b*) That article IX of the compact be amended to place all orders in effect by a two-thirds majority of the commissioners and deleting the following clause from the first paragraph of article IX.

> * * * and no such order upon a municipality, corporation, person, or entity in any State shall go into effect unless and until it receives the assent of not less than a majority of the commissioners from such State.

(*c*) That the proposed Ohio River Valley Water Sanitation Commission take control over all existing and future sources of pollution,

including acid drainage from mines other than that specifically recommended for correction by the Federal Government, affecting the normal use of water in another State.

(*d*) That the commission determine and designate stream usage of all streams in the basin including those intrastate in character, advising the proper State agency of their findings and decisions but issuing no orders on intrastate streams unless the pollution adversely affects the normal use of the water in another State.

(*e*) That the States develop local procedures for administrative, political, and fiscal programs which would facilitate the installation, maintenance, and operation of treatment plants. The development of sewerage districts, sewer-rental programs, city-county integration and other such activities by the States are virtually prerequisites for successful pollution abatement.

(*f*) That all applications for Federal aid (hereinafter recommended) be processed through the commission which shall forward all data, together with its recommendations, to the United States Public Health Service for the necessary Federal administrative action with respect to such aid.

C. FEDERAL PARTICIPATION

209. Since successful completion of the recommended program for abatement of pollution in the Ohio River Basin involves effective and active State control and participation, as well as financial and technical aid on the part of the Federal Government, the following recommendations are made subject to the fulfillment of State cooperation recommended in paragraph 208 to the satisfaction of the Surgeon General.

(*a*) That the United States Public Health Service be authorized to make grants (say 35 percent of the construction cost) to States, their political subdivisions, and municipalities within the basin to assist in financing the cost of pollution-abatement projects as recommended in paragraph 207.

(*b*) That the United States Public Health Service be authorized, upon such terms as it may deem necessary for the protection of the United States, to make loans to States, their political subdivisions, and municipalities, toward the construction cost of all pollution-abatement projects recommended in paragraph 207.

(*c*) That the United States Public Health Service, in acting upon all requests for the allocation of Federal funds, give preference to those projects which are essential for the protection of water supplies and navigation.

210. Since some of the work and functions on the part of the Federal Government are independent of initial cooperation by the States, it is recommended:

(*a*) That the Director of the Bureau of Mines be authorized to complete the present limited (1940 restrictions) mine-sealing program at an estimated cost of approximately $5,500,000.

(*b*) That the Director of the Bureau of Mines be authorized to inspect and maintain all existing and newly constructed mine seals and to conduct investigations into ways and means of further reducing the amount of acid reaching the stream from the mines at a cost not to

exceed $1,000,000 annually for a period of 15 years and that additional funds be appropriated as required to extend the scope of the mine-sealing program.

(*c*) That Congress authorize an annual appropriation to the United States Public Health Service sufficient to cover the cost of—

(1) Reviewing and acting upon requests for allocation of Federal funds required to finance abatement projects.

(2) Supervising the actual construction of the projects to insure that all Federal interests are protected.

(3) Conducting a program of research to discover new and more economical methods of waste treatment.

(4) Informing the public of the need for pollution abatement.

(*d*) That the United States Public Health Service be authorized to utilize an appropriate agency of the United States, designated by the President, for the purpose of reviewing the title, locations, plans, and specifications for the construction of treatment works and of supervising actual construction to insure that all Federal interests are protected.

THOMAS M. ROBINS,
Major General,
Assistant Chief of Engineers.

RALPH E. TARBETT,
Sanitary Engineer Director,
United States Public Health Service.

ABEL WOLMAN,
Consulting Engineer,
Baltimore, Md.

WASHINGTON, D. C., *April 20, 1943.*

APPENDIXES

Appendix A

ALLEGHENY RIVER BASIN

SUMMARY

211. *General description.*—The Allegheny River Basin has a drainage area of 11,730 square miles. There are 9,775 square miles of the basin in western Pennsylvania, the remainder are in southwestern New York. The river flows across the Allegheny Plateau in a well-defined valley, which has more or less precipitous sides, and joins the Monongahela River at Pittsburgh, Pa., to form the Ohio River. Valley elevations range from about 700 to about 3,000 feet above mean sea level. The eastern portion of the basin is for the most part rugged and drained by many tributaries, the remainder of the basin is less rugged. Principal tributaries are the Kiskiminetas and Clarion Rivers, and Crooked, Mahoning, Redbank, Tionesta, Conewango, and French Creeks. A general map of the basin is shown on plate 12.

212. Coal mining and steel production are the most important basin industries. Brewing, canning, meat packing, oil refining, tanning, and the manufacture of byproduct coke, pulp and paper, and textiles are of significance and the sources of appreciable quantities of industrial sewage. Dairying and farming are also practiced in the basin. Natural resources, in addition to coal, include oil, limestone, building and glass sands, gravel, fire clays, shales, and second-growth timber.

213. Excellent water power resources exist but have not been developed fully, due to the competition of steam power which can be produced at relatively low cost because of cheap fuel. The main river is canalized for 72 miles above its mouth, and navigation facilities are used extensively. The Corps of Engineers has completed four flood-control reservoirs in the basin; namely, Crooked Creek, Loyalhanna, Mahoning, and Tionesta Reservoirs. Four additional reservoirs are authorized and eligible to be selected for construction by the Chief of Engineers. The largest of these would be located on the Allegheny River above Warren, Pa., and would include storage capacity for low flow regulation.

214. The urban population of the basin increased steadily prior to 1930, but decreased slightly during the past decade, while rural population has increased steadily for a long period. The present population of the basin, exclusive of Pittsburgh, Pa., approximates 1,236,700. About 42 percent of this number is urban. Principal communities and their populations (1940 census) are as follows:

Johnstown, Pa	66, 668	Oil City, Pa	20, 379
Jamestown, N. Y	42, 638	Meadville, Pa	18, 919
New Kensington, Pa	24, 055	Bradford, Pa	17, 691
Olean, N. Y	21, 506		

215. *Water uses.*—There are 225 public water supplies in the basin. These serve about 1,545,000 persons. Ninety-one surface supplies, aggregating 139.38 million gallons per day, serve 82 percent of the population which uses public supplies. Over 920,000 persons, or about 60 percent of the population using public water supplies, are served from 21 surface sources which are subject to pollution from community sewer outfalls. All communities using polluted surface supplies practice coagulation, sedimentation, filtration, and chlorination. Three of these plants also employ lime-soda softening.

216. The quality of the streams used for water supplies is generally good, except where damaged by acid mine drainage and domestic and industrial wastes. Low natural alkalinity and hardness are characteristic; hence, acid mine drainage presents a more serious problem in the Allegheny River Basin than in basins where the natural alkalinity of the streams is higher.

217. Many clean streams in the mountainous northern regions are extensively used for recreation, as are Chautauqua Lake, Conneaut Lake, and other natural and artificial lakes in the basin. Piney power plant, on the Clarion River, is the only sizable hydroelectric development. Industrial water supply is of considerable importance.

218. Low flow characteristics at three selected stream stations in the basin are as follows:

Stream	French Creek	Clarion River	Kiskiminetas River
Location	Saegerstown, Pa.	Piney, Pa.	Avonmore, Pa.
Drainage area (square miles)	629	980	1,723
Period considered	1921-39	1924-39	1907-37
June to September discharge (cubic feet per second):			
Minimum single month	36	81	90
Minimum 4-month average	52	162	408
Average	282	509	1,414

219. *Sources of pollution.*—About 919,800 persons, or 61 percent of the population of the basin, are served by sewers. Of these, 273,600 live within the city limits of Pittsburgh, Pa. Industrial wastes, after application of various corrective measures now practiced, have a net population equivalent of 678,400 (based on biochemical oxygen demand), of which 5,200, or less than 1 percent, receive further treatment in municipal plants. About 40 percent of the industrial wastes of the basin enter the Allegheny River in the 30-mile reach below the mouth of the Kiskiminetas River. Twenty-two primary and nineteen secondary municipal waste treatment plants, in which about $5,460,000 have been invested, serve 109,000 and 55,300 persons, respectively, and reduce the combined population equivalent of domestic and industrial wastes, as discharged, to about 1,514,400. Summarized data follow:

Waste sources:		
Total population (1940 census):		
Pittsburgh, Pa. (Allegheny River portion)	283, 440	
Remainder of Allegheny River Basin	1, 236, 694	
		1, 520, 134
Sewered population:		
Connected to municipal treatment	164, 300	
Not connected to municipal treatment	755, 500	
		919, 800

Waste sources—Continued.			
Industrial wastes (population equivalent after application of independent corrective measures now in force, but prior to other treatment):			
Connected to municipal treatment		5, 200	
Not connected to municipal treatment:			
Brewing	53, 800		
Byproduct coke	84, 000		
Canning	57, 900		
Chemical	9, 600		
Distilling	19, 600		
Meat	90, 600		
Milk	17, 900		
Oil refining	35, 900		
Paper	94, 400		
Tanning	63, 700		
Textile	124, 300		
Miscellaneous	21, 500		
		673, 200	
			678, 400
Total (population equivalent)			1, 598, 200
Wastes as discharged:			
Human wastes (sewered) (population equivalent after all present treatment):			
Connected to municipal treatment		82, 500	
Not connected to municipal treatment		755, 500	
			838, 000
Industrial wastes (population equivalent after all present treatment):			
Connected to municipal treatment		3, 200	
Not connected to municipal treatment		673, 200	
			676, 400
Total waste residual (population equivalent)			1, 514, 400

NOTE.—Single industries of a specific classification are included within the miscellaneous classification.

220. The intensity of pollution from acid mine drainage is second only to that in the Monongahela River Basin and amounts to about 375,400 tons of acid per year (calcium carbonate equivalent). Over 82 percent of the mine acid load is discharged in the basin of the tributary Kiskiminetas River, the most heavily acid large stream in the entire Ohio River Valley. Prior to the inception of mine sealing the acid load was about 9 percent higher than the above figure.

221. Spent acid discharges from steel-mill pickling operations amount to about 3,375 tons per year (calcium carbonate equivalent), all of which is discharged to the Kiskiminetas and lower Allegheny Rivers.

222. *Extent of pollution.*—During the period from July to December 1940, the Public Health Service collected and analyzed more than 765 water samples from over 240 stream stations in the basin. Fifty-seven percent were collected during July, August, and September, and the remainder in October, November, and December. Average discharge on the days of sampling during the summer and fall months was less than half the mean June to September discharge of record.

223. Average monthly dissolved oxygen results of less than 5 parts per million were observed at about 11 percent of the stations on normal streams and at 5 percent on acid streams. The lowest results were observed below Corry, Johnsonburg, Kane, Clarion, Bradford, and Latrobe, Pa.

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224. At approximately 75 percent of the stations on both normal and acid streams monthly average biochemical oxygen demands of less than 3 parts per million were observed. At about 15 percent of the stations on normal streams and 5 percent on acid streams average oxygen demands of over 5 parts per million were observed. The worst conditions were found on tributaries below Kane, St. Marys, Johnsonburg, DuBois, Derry, and Ridgeway, Pa.

225. Average monthly coliform counts of more than 200 per milliliter were observed at 24 percent of the stations on normal streams and at less than 3 percent of the stations on acid streams, thus indicating the effect of acid pollution in reducing coliform bacteria densities. The highest coliform counts were observed below Kane, Corry, DuBois, and Derry, Pa.

226. Acid stream conditions were observed at approximately one-third of the sampling stations in the basin. The range of pH values was from 2.4 to 6.9. In addition to the main Kiskiminetas River, where the highest concentration of acid in the Allegheny River Basin was observed, Mahoning Creek, Crooked Creek, Cowanshannock Creek, and Loyalhanna Creek showed evidence of pollution by acid mine drainage.

227. Results of analyses for 12 sampling dates during the period September to December 1940 showed the dissolved oxygen content, the coliform bacteria content, and the pH value of the Allegheny River at its mouth to be higher and the biochemical oxygen demand to be lower than those at the mouth of the Monongahela River on most of the sampling dates. Plates 12, 13, 14, and 15 include data on sources of coliform bacteria, dissolved oxygen, and pH results.

228. *Methods of pollution control.*—The major pollution problems in the Allegheny River Basin are caused by acid mine drainage; industrial wastes, particularly in the Clarion River Basin; and domestic sewage, particularly in the vicinity of Pittsburgh.

229. Control of acidity can best be accomplished by a combined program of mine sealing and low flow regulation. Storage in the required amount for low flow regulation could be provided incidental to flood-control operations in reservoirs built and authorized in the basin or as a separate feature in the authorized Allegheny River Reservoir.

230. All of the industries in the Clarion River Basin have taken steps to reduce pollution, but any major improvement in conditions there will require the development of better industrial waste-treatment techniques if plant operations continue at the present level.

231. Primary treatment and chlorination should be adequate for all municipal sewage from the Pittsburgh area. All or most of the wastes entering the streams in this region could be most economically treated at a large plant on the Ohio River. Primary sewage treatment should also be adequate for communities on the Allegheny River proper with the exception of Olean, N. Y., and Coudersport, Pa.; and adequate at Johnstown and Latrobe, Pa., and at other communities on strongly acid streams. Secondary treatment appears to be necessary at Bradford and DuBois, Pa., and at five smaller communities in the upper part of the basin, located on streams subject to near-zero flows. Supplemental treatment is suggested at seven communities, including Jamestown and Olean, N. Y.

232. The estimated cost of a suggested program of pollution control is shown in the following table. The program would eliminate local nuisance, improve streams for use as public water supplies, and restore and improve streams for recreational purposes.

Suggested program of pollution control for the Allegheny River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primary	86	[1] 654,300	863, 400	586, 500	$5, 070, 000	$235, 000	$360, 000	$595, 000
Secondary	7	57, 900	58, 600	70, 400	890, 000	50, 000	60, 000	110, 000
Improvements	7	79, 600	77, 300		390, 000	20, 000	30, 000	50, 000
Subtotal	100	[1] 791,800	999, 300		6, 350, 000	305, 000	450, 000	755, 000
Interceptors					3, 670, 000	(2)	170, 000	170, 000
Industrial treatment	(3)				660, 000	140, 000	90, 000	230, 000
Mine sealing	(4)				1, 460, 000	158, 000	61, 000	219, 000
Subtotal					12, 140, 000	603, 000	771, 000	1, 374, 000
Emergency allowance, 20 percent [5]					2, 430, 000			
Total					14, 570, 000			

[1] Includes some population to be served in Ohio River plants.
[2] Negligible.
[3] Includes such items as minor corrections, process changes, sewer construction, treatment plants, etc.
[4] Initial program contemplates sealing of 164,960 ton-years of acid.
[5] Estimated additional cost of program if provided during the present emergency period.

Appendix B

MONONGAHELA RIVER BASIN

SUMMARY

233. *General description.*—The Monongahela River drains an area of 7,380 square miles. Its watershed embraces the southwest corner of Pennsylvania and the northeast portion of West Virginia, and includes a small section of western Maryland. The river flows across the rugged Appalachian Plateau, through narrow valleys that are several hundred feet below the uplands, and joins the Allegheny River at Pittsburgh, Pa., to form the Ohio River. Valley elevations range from about 700 to about 4,700 feet above mean sea level. Principal tributaries are the Youghiogheny, Cheat, Tygart, and West Fork Rivers. A general map of the basin is shown on plate 16.

234. Coal mining and steel production in the basin are of sufficient magnitude to be of national importance. Brewing, dairying, distilling, meat packing, tanning, and the manufacture of byproduct coke and chemicals are extensively practiced in the valley. Natural resources in addition to coal include limestone, gas, and abundant water power.

235. The Monongahela River is canalized for its entire length. It is one of the most intensively used inland waterways in the world.

Tygart Reservoir, located above Grafton, W. Va., and Youghiogheny Reservoir, now under construction above Confluence, Pa., are Federal projects to provide flood control and low-flow regulation in the basin.

236. The urban population of the basin increased considerably between 1910 and 1930, but only slightly in the past decade. The rural population has shown a slight, uniform increase in the past 3 decades. The present population of the basin, exclusive of Pittsburgh, Pa., is about 1,264,700, of which 46 percent is urban. Principal communities and their populations (1940 census) are as follows:

McKeesport, Pa	55, 355	Uniontown, Pa	21, 819
Clarksburg, W. Va	30, 579	Duquesne, Pa	20, 693
Wilkinsburg, Pa	29, 853	Monessen, Pa	20, 257
Fairmont, W. Va	23, 105		

237. *Water uses.*—There are 153 public water supplies in the basin of which 98, aggregating about 59.42 million gallons per day and serving 811,200 persons, are from surface sources. About 84 percent of the population using public water supplies is served by 57 surface supplies subject to pollution from community sewer outfalls. Most of the communities using polluted surface waters practice coagulation, sedimentation, filtration, and chlorination. Five plants also employ softening processes. The acidity of surface waters presents unsual problems in treatment and corrosiveness. Twenty public surface water supplies from the main stream have average pH values ranging from 4.0 to 5.0 in the raw water.

238. Several reservoirs are intensively used for recreation, as are many clean streams in the eastern part of the basin. The acidity of the main stream, the high degree of industrial development along its banks, and the intensive use of the stream for commercial navigation prevent satisfactory recreational use of the Monongahela River proper. Two hydroelectric developments on tributary streams have been constructed by private interests and have provided some beneficial regulation during periods of low flow. There is extensive use of surface waters for industrial purposes.

239. Low flow characteristics at four selected stream stations in the basin are as follows:

Stream	Youghiogheny, River	Cheat River	Tygart River	West Fork River
Location	Sutersville, Pa.	Pisgah, W. Va.	Fetterman, W. Va.	Clarksburg, W. Va.
Drainage area (square miles).	1,715	1, 360	1, 304	384
Period considered	1920–36, 1939	1927–39	1907–38	1923–39
June to September discharge (cubic feet per second):				
Minimum single month	185	43	4	4
Minimum 4-month average	566	452	151	8
Average	1, 314	1, 356	1, 211	224

240. *Sources of pollution.*—About 862,200 persons, or 58 percent of the total population of the basin, are served by sewers. Of these, 210,600 live within the city limits of Pittsburgh, Pa. Industrial wastes contribute an additional net population equivalent of 426,300 after application of various corrective measures now in use (based on biochemical oxygen demand). Less than 0.5 percent of these latter

wastes receive municipal treatment. Almost 50 percent of the combined organic pollution load enters the main stream in the 15.6-mile reach below the Youghiogheny River. Of 86 industrial establishments which are sources of wastes which do not receive municipal treatment, 26 have taken at least minor corrective measures to reduce pollution of the streams. Thirteen primary and seven secondary municipal waste-treatment plants, in which about $1,500,000 have been invested, serve 45,800 and 20,300 persons, respectively, and aid in reducing the combined population equivalent of domestic and industrial wastes, as discharged, to about 1,254,700. Summarized data follow:

Waste sources:			
Total population (1940 census):			
Pittsburgh, Pa. (Monongahela River portion)		218, 289	
Remainder of Monongahela River Basin		1, 264, 674	
			1, 482, 963
Sewered population:			
Connected to municipal treatment		66, 100	
Not connected to municipal treatment		796, 100	
			862, 200
Industrial wastes (population equivalent after application of independent corrective measures now in force, but prior to other treatment):			
Connected to municipal treatment		2, 000	
Not connected to municipal treatment:			
Brewing	49, 100		
Byproduct coke	240, 000		
Distilling	94, 000		
Meat	6, 100		
Milk	3, 300		
Tanning	25, 000		
Textile	1, 000		
Miscellaneous	5, 800		
		424, 300	
			426, 300
Total (population equivalent)			1, 288, 500
Wastes as discharged:			
Human wastes (sewered) (population equivalent after all present treatment):			
Connected to municipal treatment		33, 100	
Not connected to municipal treatment		796, 100	
			829, 200
Industrial wastes (population equivalent after all present treatment):			
Connected to municipal treatment		1, 200	
Not connected to municipal treatment		424, 300	
			425, 500
Total waste residual (population equivalent)			1, 254, 700

NOTE.—Single industries of a specific classification are included within the miscellaneous classification.

241. Pollution by mine drainage in the Monongahela River Basin is more intense than in any other major subbasin of the Ohio River Valley. Mine sealing has reduced the original acid load by an average of about 30 percent, leaving a residual acid load of about 646,000 tons per year (calcium carbonate equivalent).

242. Free acid in waste pickle liquor discharged by the metallurgical industries approximates 28 tons per day, or about 7,000 tons per year (calcium carbonate equivalent). Acid salts also are discharged from this source.

243. *Extent of pollution.*—During the period from May to December 1940, the Public Health Service collected and analyzed a total of more than 675 water samples from over 160 stream stations in the basin. In West Virginia this work was done with the cooperation of the State water commission. In general, flows on sampling days appeared to be several times greater than the mean June to September flows of record.

244. During the period from May to October 1940, up to 2 monthly averages of dissolved oxygen content, based on from 1 to 4 samples each, were observed to be less than 5 parts per million in the vicinity of Clarksburg and East Salem, W. Va., and below Masontown, Waynesburg, Fairbank, Republic, Uniontown, Ellsworth, Somerset, Mount Pleasant, Greensburg, Jeannette, Trafford, Turtle Creek, and Wilkinsburg, Pa., all of which communities discharge wastes to small tributaries. Similar conditions were observed at the mouth of the Monongahela River at Pittsburgh, Pa. Complete oxygen depletion, denoting septic conditions, was observed below Jeannette, Pa., in a single sample collected during October 1940.

245. Monthly average biochemical oxygen demand results of 5 parts per million or more, based on from 1 to 5 samples each, were observed below Youngwood, Irwin, and Pitcairn, Pa., which are located on small tributaries, and below each of the communities referred to in the preceding paragraph, except Ellsworth, Pa.

246. Monthly average coliform bacteria counts were in general agreement with dissolved oxygen and oxygen demand results in indicating the more severely polluted stream reaches. Highest values were observed below Waynesburg, Mount Pleasant, and Jeannette, Pa.

247. The major stream pollution problem in the basin results from acid mine drainage. Acid stream conditions were observed at 95 sampling stations in the basin with pH values ranging from 2.5 to 6.9, and phenolphthalein acidities from less than 1 part per million to over 8,000 parts per million.

248. Results of analyses of samples collected on 12 days during the period September to December 1940 showed the dissolved oxygen content, pH value, and coliform bacteria content of the Monongahela River at its mouth to be lower, and the biochemical oxygen demand to be higher than those of the Allegheny River at its mouth, on most of the sampling dates. Plates 16, 17, 18, and 19 include data on sources of pollution, and on coliform bacteria, dissolved oxygen and pH results.

249. *Methods of pollution control.*—Up to the present time, uncorrected mine acid pollution has served as a deterrent to organic pollution abatement activities. It is desirable that mine acid control and organic pollution abatement be carried on as parallel programs since both measures are necessary if reasonable restoration of stream quality is to be obtained. A combined program of mine sealing and low-flow regulation seems to offer the best solution to the mine acid problem.

250. Secondary domestic waste treatment is indicated at 16 communities located on streams subject to low summer flows; primary treatment is indicated at 66 communities in the basin, including the Pittsburgh area, and supplementary treatment is indicated at a single community.

251. Industrial waste treatment to reduce pickle liquor and phenol discharges is indicated to be desirable.

252. The cost of a suggested program of pollution control is shown in the following table. The program would eliminate local nuisance, improve streams for use as public water supplies, and restore portions of the streams for recreational use.

Suggested program of pollution control for the Monongahela River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primary	66	[1]683,400	764,100	476,500	$4,710,000	$130,000	$330,000	$460,000
Secondary	16	92,800	102,300	105,000	1,480,000	65,000	100,000	165,000
Improvements	1	25,000	21,800		80,000	75,000	10,000	85,000
Subtotal	83	[1]801,200	888,200		6,270,000	270,000	440,000	710,000
Interceptors					5,870,000	(2)	275,000	275,000
Industrial treatment	(3)				1,110,000	320,000	150,000	470,000
Mine sealing	(4)				1,600,000	173,000	67,000	240,000
Subtotal					14,850,000	763,000	932,000	1,695,000
Emergency allowance, 20 percent [5]					2,970,000			
Total					17,820,000			

[1] Includes some population to be served in Ohio River plants.
[2] Negligible.
[3] Includes such items as minor corrections, process changes, sewer construction, treatment plants, etc.
[4] Initial program contemplates sealing of 198,680 ton-years of acid.
[5] Estimated additional cost of program if provided during the present emergency period.

Appendix C

BEAVER RIVER BASIN

SUMMARY

253. *General description.*—The Mahoning and Shenango Rivers merge at New Castle, Pa., to form the Beaver River, which flows through narrow valleys across rugged plateau land to join the Ohio River 25.4 miles below Pittsburgh, Pa. The basin comprises a drainage area of 3,145 square miles situated in western Pennsylvania and eastern Ohio. Connoquenessing, Slippery Rock, and Neshannock Creeks are the important tributaries. A general map of the basin is shown on plate 20.

254. Steel production is the most important industry in the basin. The production of the so-called Youngstown District is of Nation-wide significance. Dairying, farming, meat packing, brewing, and the manufacture of byproduct coke and miscellaneous other items are of lesser economic importance. Natural resources include sand, coal, limestone, sandstone, clay, shale, gravel, oil, and gas. Tillable soil and temperature favor agriculture.

255. There are no particularly attractive water power sites in the basin, and commercial navigation is restricted to the limits of slack

water provided by Montgomery Dam on the Ohio River. In addition to several domestic water supply reservoirs, Milton Reservoir on the Mahoning River, Ohio, and Pymatuning Reservoir on the Shenango River, Pa., have been constructed by non-Federal interests to provide flood control, low water regulation, and aquatic recreational facilities. In 1942 the Corps of Engineers initiated construction of Berlin Reservoir, at a site on the Mahoning River above the Youngstown area, to provide low flow regulation and flood control.

256. Both the rural and urban populations of the basin have increased rapidly for several decades. The present population of approximately 728,400 is about 66 percent urban. Principal communities and their populations (1940 census) are as follows:

Youngstown, Ohio	167, 720	Sharon, Pa	25, 622
New Castle, Pa	47, 638	Butler, Pa	24, 477
Warren, Ohio	42, 837	Alliance, Ohio	22, 405

257. *Water uses.*—There are 50 public water supplies, of which 18, serving 499,200 persons and aggregating 40.88 million gallons per day, are from surface sources. Twelve of the latter, serving 430,400 people, are from streams or reservoirs subject to pollution. The supplies from the Beaver and Mahoning Rivers are seriously polluted and thorough treatment often fails to produce a palatable water.

258. Industrial cooling water requirements in the Youngstown area frequently are as much as 20 times as great as minimum unregulated stream flow. This condition necessitates reuse of water, with resultant increases in stream temperatures which aggravate the already serious effects of pollution. Because of pollution, aquatic recreational activities are restricted to the smaller streams of the basin, except in the Milton and Pymatuning Reservoir areas.

259. Low flow characteristics at three selected stream stations in the basin are as follows:

Stream	Mahoning River	Shenango River	Beaver River
Location	Youngstown, Ohio	Sharon, Pa.	Wampum, Pa.
Drainage area (square miles)	899	608	2, 235
Period considered	1921–39	1909–38	1914–18 1932–39
June to September discharge (cubic feet per second)	(1)	(2)	(1 2)
Minimum single month	47	7	153
Minimum 4-month average	96	41	309
Average	388	219	863

1 Reflects flow regulation by Milton Reservoir.
2 Reflects flow regulation by Pymatuning Reservoir.

260. *Sources of pollution.*—About 515,700 persons, or 71 percent of the population of the basin, are served by sewers. Industrial wastes, after application of various corrective measures now employed by industry, have a net population equivalent to 164,400 (based on biochemical oxygen demand), of which about 7 percent receives further treatment in municipal sewage-treatment plants. Seventeen primary and eighteen secondary municipal treatment plants, in which about \$4,760,000 have been invested, serve 134,300 and 84,100 persons, respectively. The combined population equivalent of domestic and industrial

wastes as discharged after treatment is 558,400, of which about 95 percent is discharged in the Warren-Lowellville reach of the Mahoning River. Summarized data follow:

Waste sources:			
Total population (1940 census)			728, 368
Sewered population:			
Connected to municipal treatment		218, 400	
Not connected to municipal treatment		297, 300	
			515, 700
Industrial wastes (population equivalent after application of independent corrective measures now in force, but prior to other treatment):			
Connected to municipal treatment		11, 800	
Not connected to municipal treatment:			
Brewing	5, 300		
Byproduct coke	80, 400		
Meat	7, 200		
Milk	3, 400		
Miscellaneous	56, 300		
		152, 600	
			164, 400
Total (population equivalent)			680, 100
Wastes as discharged:			
Human wastes (sewered) (population equivalent after all present treatment):			
Connected to municipal treatment		102, 700	
Not connected to municipal treatment		297, 300	
			400, 000
Industrial wastes (population equivalent after all present treatment):			
Connected to municipal treatment		5, 800	
Not connected to municipal treatment		152, 600	
			158, 400
Total waste residual (population equivalent)			558, 400

NOTE.—Single industries of a specific classification are included within the miscellaneous classification.

261. Additional pollutants of significance include an acid load of 15,100 tons per year from coal-mine drainage and 8,000 tons per year of free acid in waste pickle liquor discharged by metallurgical industries (calcium carbonate equivalent). Phenols discharged by 4 byproduct coke plants are responsible for difficult water treatment problems.

262. *Extent of pollution.*—The Public Health Service collected and analyzed more than 350 water samples from over 60 stream stations in the basin. Eighty-two percent were collected during June, July, and August 1940, the remainder in October, November, and December of the same year. Average discharge during the summer period was about twice as great as the mean June to September discharge of record, although the average flow on sampling days appears, in general, to have been somewhat closer to the mean for the June to September period. Plates 20, 21, and 22 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results, respectively. Reaches showing the greatest extent of pollution are the following:

(*a*) Mahoning River between Warren and Lowellville, Ohio, a distance of 25 river miles: Samples collected at each of 10 stream stations during June, July, and August 1940 had monthly dissolved oxygen content averages varying from 7.8 parts per million to zero.

Zero or near-zero values were observed below Warren, Niles, Youngstown, and Lowellville, Ohio. Monthly average coliform bacteria counts ranged from 12 to 11,000 per milliliter. From 4 to 9 samples were represented in each average. Flows varied during the sampling period but on the sampling days were generally lower than average summer flows.

(*b*) Shenango River below Sharon, Pa.: Two samples collected during August 1940 had an average dissolved oxygen content of 3.2 parts per million and an average coliform bacteria count of 3,500 per milliliter. The biochemical oxygen demand was 7.5 parts per million. Discharge was less than summer average.

(*c*) Beaver River below New Castle, Pa.: Three samples collected during August 1940 had an average dissolved oxygen content of 3.3 parts per million and an average coliform bacteria count of 437 per milliliter. The biochemical oxygen demand was 11.5 parts per million. Discharge was less than summer average.

Serious oxygen depletion was not noted in other than the Youngstown district except locally, below pollution sources on small tributaries.

263. Results of analyses for 31 sets of water samples collected during the period October 1940 to January 1941 showed the Beaver River at its mouth to be lower in dissolved oxygen content and higher in biochemical oxygen demand and coliform bacteria content than was the Ohio River above their confluence on the majority of sampling days.

264. *Methods of pollution control.*—Corrective measures may be effectively applied to pollutants found in the Beaver River Basin. The best adapted plan for organic pollution control in the Youngstown district appears to be the provision of 10 chemical sewage treatment plants and additional low flow regulation. Berlin Reservoir is an initial step in this direction.

265. Secondary treatment is indicated to be necessary at five small towns where the stream flows are now inadequate for satisfactory waste dilution. Primary treatment is indicated at four other communities. Additions to or improvement of the existing waste treatment facilities of eight communities in the basin are necessary. Industrial waste treatment, primarily to reduce phenol discharges at byproduct coke plants, appears to be necessary.

266. The cost of a suggested program of pollution control is shown in the following table. The program would eliminate local nuisance, improve public water supplies, and restore portions of the streams for recreation. Incidental benefits would accrue to industrial water users if additional low flow regulation were provided for organic pollution control in the Youngstown area.

Suggested program of pollution control for the Beaver River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primar	[1] 14	293,300	295,000	361,900	$2,660,000	$178,000	$190,000	$368,000
Secondary	5	3,800	5,700	7,700	160,000	6,000	10,000	16,000
Improvements	8	82,600	85,400		150,000	6,000	10,000	16,000
Subtotal	[1] 27	379,700	386,100		2,970,000	190,000	210,000	400,000
Interceptors					1,990,000	(2)	95,000	95,000
Industrial treatment	(3)				1,040,000	235,000	135,000	370,000
Mine sealing	(4)				50,000	6,000	2,000	8,000
Subtotal					6,050,000	431,000	442,000	873,000
Emergency allowance, 20 percent [5]					1,210,000			
Total					7,260,000			

[1] Includes 10 chemical sewage-treatment plants.
[2] Negligible.
[3] Includes such items as minor corrections, process changes, sewer construction, treatment plants, etc.
[4] Initial program contemplates sealing of 6,500 ton-years of acid.
[5] Estimated additional cost of program if provided during the present emergency period.

Appendix D

MUSKINGUM RIVER BASIN

SUMMARY

267. *General description.*—The Muskingum River Basin has a drainage area of 8,040 square miles, and embraces the central and southern portions of eastern Ohio. Headwaters of the northerly and westerly tributaries rise in an area of glacial drift and flow across the Allegheny Plateau. The main stream joins the Ohio River 172.2 river miles below Pittsburgh, Pa. Principal tributaries are the Licking, Walhonding, and Tuscarawas Rivers and Wills Creek. A general map of the basin is shown on plate 23.

268. The natural resources of the basin include coal, clay, shales, gas, oil, limestone, sandstone, salt, sand, and gravel. Fertile soil and climate favor agriculture. Manufacturing is the leading economic pursuit. Paperboard, strawboard, and machinery; and ceramic, chemical, rubber, dairy, iron and steel products are among the goods produced. The Muskingum River is navigable, but facilities are inadequate for effective modern navigation. The streams of the basin are not well adapted to the development of water power on a commercial scale.

269. The population of the basin has increased 31 percent since 1910, to a present figure of about 812,000. Approximately half of the present population is urban. Principal communities and their populations (1940 census) are as follows:

Canton	108, 401	Newark	31, 487
Zanesville	37, 500	Massillon	26, 644
Mansfield	37, 154	Barberton	24, 028

270. *Water uses.*—There are 94 public water supplies in the basin of which 9, serving 140,400 persons and aggregating 11.98 million gallons per day, are from surface sources. Four of the surface supplies are subject to pollution by domestic wastes. Ground water is plentiful but is usually hard and sometimes must be treated to remove iron.

271. A system of 14 flood control reservoirs of which 11 have conservation pools, together with Buckeye Lake and the Portage Lakes, furnish the area with fine aquatic recreational facilities which are extensively used. The lower Muskingum River and Wakatomica Creek are outstanding fishing streams. Use of water for industrial purposes is increasing.

272. Low flow characteristics at three selected stream stations in the basin are as follows:

Stream	Muskingum River	Tuscarawas River	Licking River
Location	Dresden	Dover	Toboso
Drainage area (square miles)	5,982	1,398	672
Period considered	1922–39	1924–39	1922–39
June to September discharge (cubic feet per second):			
Minimum single month	483	188	52
Minimum 4-month average	768	270	65
Average	3, 140	770	351

273. *Sources of pollution.*—About 422,600 persons, or 52 percent of the population of the basin, are served by sewers. The population equivalent of industrial wastes is high, and approximates 320,600 after application of various corrective measures by industry (based on biochemical oxygen demand). At least minor corrective measures have been taken by 56 of the 84 industrial establishments whose wastes are not connected to municipal treatment. About 75 percent of the industrial sewage not treated in municipal plants comes from 4 strawboard and paperboard factories. An industrial waste population equivalent of 40,100 receives further treatment in municipal sewage treatment plants. Thirteen primary and 18 secondary municipal treatment plants, in which about $4,550,000 have been invested, serve 78,700 and 206,900 persons, respectively. The population equivalent of industrial and domestic wastes, as finally discharged to the streams, is about 492,200. Summarized data follow:

Waste sources:			
Total population (1940 census)		812, 028	
Sewered population:			
Connected to municipal treatment		285, 600	
Not connected to municipal treatment		137, 000	
			422, 600
Industrial wastes (population equivalent after application of independent corrective measures now in force, but prior to other treatment):			
Connected to municipal treatment		40, 100	
Not connected to municipal treatment:			
Brewing	7, 100		
Byproduct coke	14, 200		
Meat	17, 500		
Milk	6, 300		
Oil refining	11, 400		
Paper	210, 000		
Miscellaneous	14, 000		
		280, 500	
			320, 600
Total (population equivalent)			743, 200
Wastes as discharged:			
Human wastes (sewered) (population equivalent after all present treatment):			
Connected to municipal treatment		68, 800	
Not connected to municipal treatment		137, 000	
			205, 800
Industrial wastes (population equivalent after all present treatment):			
Connected to municipal treatment		5, 900	
Not connected to municipal treatment		280, 500	
			286, 400
Total waste-residual (population equivalent)			492, 200

NOTE.—Single industries of a specific classification are included within the miscellaneous classification.

274. Acid mine drainage and waste pickle liquors are other pollutants of significance. Mine sealing has reduced the original mine acid load in the combined Muskingum and Hocking River Basins by about 42 percent, to a present total load of about 124,400 tons per year (calcium carbonate equivalent). Most of the abandoned mines in both basins have been sealed. Larger steel plants in the Canton and Massillon areas in the Muskingum River Basin have taken steps to dispose of waste pickle liquors. The present acid load from this source is about 1,375 tons per year.

275. *Extent of pollution.*—During the period from April 1940 to March 1941 the Public Health Service collected and analyzed over 400 water samples from more than 110 stream stations in the basin. Eighty-five percent of the samples were collected during April, May, June, and July, 1940. During the latter period, average discharges were several times greater than the mean June to September flows

of record. Plates 23, 24, and 25 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results.

276. Monthly average dissolved oxygen results of 5 parts per million or less, based on one to three samples each, collected during the period May to July 1940, were observed in Chippewa Creek at Rittman, Little Chippewa Creek at Orrville, Wolf Creek at Barberton, Nimishillen Creek below Canton, Rocky Fork Creek at Mansfield, Jerome Fork below Ashland, and from Barberton to Massillon on the Tuscarawas River.

277. Monthly average biochemical oxygen demand results of 5 parts per million or more, based on one to three samples each, collected during the period May to July 1940, were observed below Barberton, Canton, Carrollton, Mansfield, New Concord, Orrville, Rittman, and Wadsworth, and in the vicinities of Minerva and Coshocton.

278. Coliform bacteria counts were generally high during the period of sampling. Highest values were observed below Brewster, Canton, Mansfield, Minerva, and Shelby; and, in the Tuscarawas River, in the Barberton to Massillon reach.

279. The effects of acid mine pollution were in evidence in Moxahala Creek Basin where pH values less than 3.0 were common during the sampling period. Extreme hardness was observed below Barberton, reaching 5,800 parts per million in a single sample collected during July 1940.

280. Results of water analyses for 63 sampling dates during the period May 1940 to March 1941, showed the dissolved oxygen content of the Muskingum River at the mouth to be higher than that of the Ohio River above their junction on 56 percent of the sampling days. The biochemical oxygen demand and coliform bacteria content of the tributary were higher than those of the Ohio River about 65 percent of the time.

281. *Methods of pollution control.*—In spite of extensive efforts to abate pollution in the Muskingum River Basin, a problem remains on the upper Tuscarawas River and some of its tributaries. Only limited additional improvement in the quality of the upper Tuscarawas River drainage system appears justified in view of the present use of the streams. Other streams can be restored to or maintained in good condition at reasonable cost.

282. Primary treatment of domestic sewage and removal of settleable solids from industrial wastes should suffice to maintain satisfactory stream conditions below 8 of the 10 urban communities now discharging untreated wastes. In addition, it appears desirable that primary treatment be employed at 16 smaller communities. Secondary treatment is indicated to be necessary at Newark and Cambridge, as well as at 18 smaller communities now without sewage treatment facilities. Improvements to existing plants appear to be necessary at Canton, Mansfield, and at 7 other smaller sources of pollution.

283. The cost of a suggested program of pollution control is shown in the following table. The program would eliminate most local nuisance conditions in the basin, improve streams for use as public water supplies, and preserve and improve the valuable aquatic recreational facilities of the area. If legal and practical obstacles can be overcome in the future, desirable low flow regulation may be provided by means of the Muskingum Conservancy District reservoirs.

Suggested program of pollution control for the Muskingum River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primary	23	88, 200	106, 900	124, 000	$1, 100, 000	$52, 000	$80, 000	$132, 000
Secondary	20	48, 400	61, 000	72, 500	1, 160, 000	48, 000	80, 000	128, 000
Improvements	9	180, 300	185, 000		390, 000	5, 000	25, 000	30, 000
Subtotal	52	316, 900	352, 900		2, 650, 000	105, 000	185, 000	290, 000
Interceptors					2, 220, 000	(1)	105, 000	105, 000
Industrial treatment	(2)				310, 000	100, 000	40, 000	140, 000
Mine sealing	(3)				[4] 110, 000	[4] 11, 000	[4] 5, 000	[4] 16, 000
Subtotal					5, 290, 000	216, 000	335, 000	551, 000
Emergency allowance, 20 percent [5]					1, 060, 000			
Total					6, 350, 000			

1 Negligible.
2 Includes such items as minor corrections, process changes, sewer construction, treatment plants, etc.
3 Initial program contemplates sealing of 19,000 ton-years of acid. See note 4.
4 Muskingum and Hocking River Basins combined.
5 Estimated additional cost of program if provided during present emergency period.

Appendix E

LITTLE KANAWHA RIVER BASIN

SUMMARY

284. *General description.*—The Little Kanawha River drains an area of 2,320 square miles situated entirely within West Virginia, and joins the Ohio River 184.6 river-miles below Pittsburgh, Pa. The basin is hilly to mountainous, with steep slopes and narrow valleys. Valley elevations range from about 560 to about 2,800 feet above mean sea level. Hughes Fork, West Fork, Steer Creek, Leading Creek, and Reedy Creek are the principal tributaries. A navigable depth of 4 feet is maintained for a distance of 48 miles above the mouth of the Little Kanawha River. There are no existing hydroelectric power developments in the basin. A general map of the area is shown on plate 26.

285. Important economic pursuits include the production of gas and oil, agriculture, manufacturing, and lumbering. Current oil production approximates 1,000,000 barrels annually, or about one-quarter of the total oil production of West Virginia. Coal production is relatively unimportant. Manufacturing is confined almost entirely to the Parkersburg area at the mouth of the Little Kanawha River.

286. The population of the basin, exclusive of Parkersburg, approximates 92,400, is essentially rural, and has not varied materially since 1910. Spencer, the largest community, has about 2,495 inhabitants. All other communities have less than 2,000 residents.

287. *Water uses.*—There are 8 public water supplies in the basin of which 5, aggregating about 0.28 million gallons per day and serving about 6,600 persons, are from surface sources. Three of the latter are from streams subject to pollution. All surface supplies are chlorinated, 4 are coagulated and settled, and 3 are filtered. In general, no serious pollution problem is present in connection with public water supplies. The upper Little Kanawha River and both forks of the Hughes River are extensively used for sport fishing. Industrial water usage is of minor importance in the basin.

288. Low-flow characteristics at two selected stream stations in the basin are as follows:

Stream	Little Kanawha River	Hughes River
Location	Palestine	Cisko
Drainage area (square miles)	1,513	453
Period considered	1912–40	1915–31 1939–40
June to September discharge (cubic feet per second):		
Minimum single month	0	0
Minimum 4-month average	7	2
Average	1,097	272

289. *Sources of pollution.*—About 10,200 persons, or 11 percent of the population of the basin, are served by sewers. Two municipal waste-treatment plants, 1 primary and 1 secondary, in which a total of about \$190,000 have been invested, serve 1,400 and 3,400 persons, respectively. These reduce the population equivalent of domestic sewage as discharged to about 6,800 (based on biochemical oxygen demand). There are no significant sources of industrial sewage in the basin, except in the Parkersburg area. The latter pollution problem primarily concerns the Ohio River. Pollution from acid mine drainage is slight, aggregating about 350 tons per year (calcium carbonate equivalent).

290. *Extent of pollution.*—During the period May 1940 to March 1941 the Public Health Service collected and analyzed more than 180 water samples from 10 stream stations in the basin. Ninety-one percent of the samples were collected during the 5-month period from May to September 1940, and the remainder, in January, February, and March 1941. Average discharges on sampling days during the early period were considerably higher than mean June to September flows of record. Results of analyses indicated that with the exception of more or less uniformly high bacterial pollution there is no extensive pollution in the Little Kanawha River Basin. Plates 26, 27, and 28 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results. Reaches showing the greatest extent of pollution are the following:

(*a*) Bennell Run below Pennsboro: Three samples collected during July 1940, had an average dissolved oxygen content of 3.7 parts per million and an average coliform bacteria count of 7,130 per milliliter. The average biochemical oxygen demand for the month was 15.8 parts per million. Discharge was less than summer average.

(*b*) Spring Creek below Spencer: Four samples collected during August 1940, had an average dissolved oxygen content of 1.7 parts

per million and an average coliform bacteria count of 3,350 per milliliter. The average biochemical oxygen demand for the month was 5.4 parts per million. Discharge was about equal to the summer average.

(*c*) Little Kanawha River at mouth: Low dissolved oxygen content, high coliform bacteria counts, and high biochemical oxygen demand were observed at the mouth of the Little Kanawha River. However, results were influenced by sewage from Parkersburg.

291. Results of analyses for 57 sampling dates during the period May 1940, to March 1941, showed that the Little Kanawha River at its mouth generally had a lower dissolved oxygen content, and higher biochemical oxygen demand and coliform bacteria count than the Ohio River above their junction. On 12 sampling dates during the period June to September 1940, the Little Kanawha River above the Parkersburg area (river mile 3.5) was similar in quality to the Ohio River above their junction.

292. *Methods of pollution control.*—The Little Kanawha River is but moderately polluted and there are no particularly difficult waste-treatment problems. The two largest communities, Spencer and Pennsboro, have treatment plants which need some improvement. Primary treatment should be sufficient to maintain good stream conditions at the remaining sources of pollution, except during such an extremely dry year as 1930. Provision against such a contingency does not seem to be justified.

293. The cost of a suggested program of pollution control, including supplemental treatment at Spencer and Pennsboro, and primary treatment at six smaller communities, is shown in the following table. The program would eliminate local nuisance conditions which now exist and would both preserve and enhance the recreational value of the area.

Suggested program of pollution control for the Little Kanawha River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primary	6	5,300	5,500	5,900	$85,000	$4,500	$5,500	$10,000
Improvements	2	4,800	5,000		5,000	500	500	1,000
Subtotal	8	10,100	10,500		90,000	5,000	6,000	11,000
Interceptors					120,000	(1)	5,000	5,000
Subtotal					210,000	5,000	11,000	16,000
Emergency allowance, 20 percent [2]					40,000			
Total					250,000			

[1] Negligible.
[2] Estimated additional cost of program if provided during the present emergency period.

Appendix F

HOCKING RIVER BASIN

SUMMARY

294. *General description.*—The Hocking River drains an area of 1,185 square miles which lies wholly within southeastern Ohio. The stream joins the Ohio River 199.3 river-miles below Pittsburgh, Pa. The basin is hilly, with moderately steep slopes, except in the glaciated headwater area which is characterized by low hills and broad valleys. The important tributaries are Federal, Sunday, Monday, Clear, and Rush Creeks. A general map of the basin is shown on plate 23.

295. Agriculture and coal mining are the principal occupations in the Hocking River Basin. Ceramic manufacturing, gas and oil production, and forestry are lesser pursuits. Natural resources, in addition to coal, gas, and oil, include brines and commercial clays.

296. Ohio River Dam No. 20 provides slack water in the lower 5 miles of the Hocking River, but there has been no commercial navigation since 1924. Scenic caves and forests in the basin are noteworthy recreational attractions. There are no existing hydroelectric developments.

297. Lancaster, the basin's largest city, has a present population of about 21,940. No other communities have as many as 10,000 inhabitants, but small communities are uniformly distributed throughout the area. The total population of the basin approximates 113,600, of which about 42 percent is urban. Although the total population has not increased appreciably since 1910, the urban population has increased by 39 percent since that date.

298. *Water uses.*—There are 16 public water supplies in the basin of which 2, aggregating 0.13 million gallons per day and serving about 3,800 persons, are from surface sources. Both of the latter are coagulated, settled, filtered, and chlorinated. All public water supplies are from underground or upland impounded sources and are not important factors in pollution problems. Industrial water supply is not of serious concern. A few tributaries and several reaches of the main river are considered fairly good fishing streams.

299. Low flow characteristics at three selected stream stations on the Hocking River are as follows:

Stream	Hocking River	Hocking River	Hocking River
Location	Lancaster	Enterprise	Athens
Drainage area (square miles)	93	460	944
Period considered	1923–32	1931–40	1915–40
June to September discharge (cubic feet per second):			
Minimum single month	12	36	40
Minimum 4-month average	15	73	54
Average	55	273	541

300. *Sources of pollution.*—About 48,400 persons are serviced by sewers and approximately half of the basin's sewered domestic wastes receive treatment in two primary and two secondary municipal plants in which about $840,000 have been invested. Over 40 percent of the sewered population is situated in Lancaster, where a secondary treatment plant is in operation. Two meat-packing houses, a brewery, a

cheese factory, and a milk-receiving station are the important sources of industrial sewage. The brewery wastes are discharged to municipal treatment and wastes from the milk-receiving plant are treated on a trickling filter. Other industrial wastes are discharged untreated. The total residual domestic and industrial waste load, as discharged to streams, has an approximate population equivalent of 36,000 (based on biochemical oxygen demand).

301. Acid mine wastes have a damaging effect on many tributaries, particularly in the Sunday and Monday Creek Valleys. Mine sealing has reduced the original acid load in the combined Muskingum and Hocking River Basins by about 42 percent, to a present load of about 124,400 tons per year (calcium carbonate equivalent).

302. *Extent of pollution.*—The Public Health Service collected and analyzed more than 260 water samples, from over 35 stream stations in the basin. Seventy-nine percent of these were collected from April to September 1940; the remainder during October and November 1939, and January 1941. Discharges on the sampling dates ranged from near minimum summer flows to flows several times greater than mean June to September discharges of record. During the summer of 1940, flow was somewhat less than the average for the June to September period. Plates 23, 24, and 25 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results. Reaches showing evidence of significant pollution are as follows:

(*a*) Hocking River: Three samples collected from the Hocking River below Lancaster, during October 1939, had an average dissolved oxygen content of 4.6 parts per million. Other dissolved oxygen results on the main stream averaged well above 5 parts per million. Biochemical oxygen demand exceeded 5 parts per million below Lancaster, in October 1939, and below Athens, in both October 1939, and January 1941. Discharge was extremely low during the October 1939, sampling period. Coliform bacteria counts generally exceeded 100 per milliliter throughout the length of the Hocking River, and monthly averages ranged from several hundred to several thousand per milliliter below Lancaster, Logan, Haydenville, Nelsonville, and Athens.

(*b*) Tributaries: Dissolved oxygen results of less than 4 parts per million were observed in single samples from Snow Creek above Murray City and from Sunday Creek below Corning. Biochemical oxygen demand in excess of 5 parts per million was observed in Sunday Creek below Corning and Jacksonville, in Sugar Creek below New Straitsville, in Red Fork Creek below Murray City, and in Little Rush Creek below New Lexington.

303. Severe acid pollution is in evidence in tributary Little Rush, Sunday, and Monday Creek Basins. In these streams pH values of 3.0 and less are not uncommon. Results of analysis of water samples collected on 19 days during the period May to September 1940, showed the dissolved oxygen content and biochemical oxygen demand of the Hocking River at the mouth to be lower than that of the Ohio River above their junction on about 60 percent of the sampling days. The coliform bacteria content of the Hocking River was lower than that of the Ohio River on about half of the sampling days.

304. *Methods of pollution control.*—Pollution problems in the Hocking River Basin, with the exception of acid mine drainage, are not severe, and are readily amenable to solution by waste treatment.

Much of the acid mine drainage is the product of active workings which cannot readily be sealed. Damages from this source are insufficient to justify low flow regulation. Primary treatment of all wastes which are now discharged to the main stream without treatment should result in satisfactory stream conditions. On tributary streams which are polluted by acid wastes, treatment other than primary does not appear to be warranted. On the remaining tributaries, secondary treatment is indicated to prevent local nuisance below pollution sources.

305. The cost of a suggested program of pollution control for the Hocking River Basin is shown in the following table. The program would eliminate local nuisance and improve present recreational facilities.

Suggested program of pollution control for the Hocking River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primary	5	21,000	25,300	33,100	305,000	$14,000	$21,500	$35,500
Secondary	2	2,400	2,500	3,600	70,000	2,500	5,000	7,500
Improvements	1	1,100	1,200		5,000	500	500	1,000
Subtotal	8	24,500	29,000		380,000	17,000	27,000	44,000
Interceptors					240,000	(1)	11,000	11,000
Mine sealing					(2)	(2)	(2)	(2)
Subtotal					620,000	17,000	38,000	55,000
Emergency allowance, 20 percent [3]					120,000			
Total					740,000			

[1] Negligible.
[2] Costs for Hocking River Basin included with those for Muskingum River Basin.
[3] Estimated additional cost of program if provided during present emergency period.

Appendix G

KANAWHA RIVER BASIN

SUMMARY

306. *General description.*—The Kanawha River Basin has a drainage area of 12,300 square miles situated in 3 States; West Virginia (8,450 square miles), Virginia (3,080 square miles), and North Carolina (770 square miles). The stream is formed by the junction of the New and Gauley Rivers and joins the Ohio River 265.7 river miles below Pittsburgh, Pa. The topography of the basin varies from wide valleys through hill country in the lower portions, to high mountains cut by deep gorges in the upper areas. Valley elevations range from about 500 to about 5,500 feet above mean sea level. A general map of the basin is shown on plate 26.

307. Coal is mined, and oil, gas, and brines are produced in the basin. Organic chemical manufacturing is an important industry and the source of much industrial sewage. Agriculture, limited forestry, electro-metallurgy, and quarrying are lesser economic pursuits. The Charleston area is a rapidly developing industrial center, the growth of which has been paced by the chemical manufacturing industry centered therein. The valley is rich in natural resources, including, in addition to those already mentioned, water power, sandstone, limestone, clays, and various minerals.

308. Urban and rural populations have increased rapidly in the last several decades. The present total population of the basin approximates 834,800, of which about 21 percent is urban. About one-sixth of the total population is centered in the Charleston metropolitan area. Principal communities with populations of 10,000 or more (1940 census) are as follows:

Charleston, W. Va	67, 914	Beckley, W. Va	12, 852
Bluefield, W. Va	20, 641	South Charleston, W. Va	10, 377

309. *Water uses.*—One hundred and eighty public water supplies in the basin serve 326,400 persons. Sixty-five of these supplies, aggregating about 15.09 million gallons per day, and serving 201,500 persons, are from surface sources. Thirty-three of the latter, aggregating about 75 percent of the total surface supply, are from streams subject to pollution. Coagulation, sedimentation, filtration, and chlorination are practiced at 28 of these plants. Three other plants employ chlorination only, a fourth applies coagulation, sedimentation and filtration, and a fifth employs sedimentation, filtration and chlorination. The domestic and industrial sewage discharged to Elk Creek damages the source of the water supply used by Charleston, W. Va., particularly during periods of low stream flow.

310. A large number of streams in the basin are extensively used for fishing, boating, and swimming; however, gross pollution from the Charleston area limits recreation in the lower Kanawha River to boating. There is considerable industrial use of surface waters in the basin.

311. Low flow characteristics at two selected stream stations are as follows:

Stream	Kanawha River	New River
Location	Kanawha Falls, W. Va.	Eggleston, W. Va.
Drainage area (square miles)	8,367	2,941
Period considered	1877–1940	1915–37
June to September discharge (cubic feet per second):		
Minimum single month	1, 290	812
Minimum 4 month average	1, 668	1, 129
Average	7, 511	2, 885

312. *Sources of pollution.*—About 226,500 persons, or 27 percent of the population of the basin, are served by sewers. Industrial wastes, after application of various corrective measures now employed, contribute an additional net population equivalent of about 1,490,200 (based on biochemical oxygen demand), of which about 97 percent is discharged to the Kanawha River in the Charleston metropolitan area. Less than 1 percent of the industrial waste load receives further treatment in municipal plants.

313. Of the 65 industrial establishments whose wastes do not receive municipal treatment, 31 have taken at least minor corrective measures toward decreasing the damaging effect of their wastes on the streams. Six primary and 6 secondary municipal waste treatment plants, in which about $1,300,000 have been invested, serve 20,900 and 28,600 persons, respectively. These aid in reducing the net population equivalent of domestic and industrial wastes to about 1,675,100, as discharged. Summarized data follow:

Waste sources:			
Total population (1940 census)		834, 845	
Sewered population:			
Connected to municipal treatment		49, 500	
Not connected to municipal treatment		177, 000	
			226, 500
Industrial wastes (population equivalent after application of independent corrective measures now in force, but prior to other treatment):			
Connected to municipal treatment		11, 100	
Not connected to municipal treatment:			
Canning	1, 600		
Chemical	1, 378, 000		
Milk	200		
Oil refining	3, 600		
Tanning	18, 700		
Textile	8, 300		
Miscellaneous	68, 700		
		1, 479, 100	
			1, 490, 200
Total (population equivalent)			1, 716, 700
Wastes as discharged:			
Human wastes (sewered) (population equivalent after all present treatment):			
Connected to municipal treatment		18, 100	
Not connected to municipal treatment		177, 000	
			195, 100
Industrial wastes (population equivalent after all present treatment):			
Connected to municipal treatment		900	
Not connected to municipal treatment		1, 479, 100	
			1, 480, 000
Total waste residual (population equivalent)			1, 675, 100

NOTE.—Single industries of a specific classification are included within the miscellaneous classification.

314. In addition to the industries listed there are 24 coal washeries, most of which have recirculating systems. However, varying amounts of fine coal particles escape, causing turbidity and culm deposits in the streams. Mine sealing has reduced mine acid pollution to a present load of about 19,100 tons per year (calcium carbonate equivalent).

315. *Extent of pollution.*—During the period from August 1939 to February 1941 the Public Health Service collected and analyzed more than 480 water samples from over 150 stream stations in the basin. Of these, 61 percent were collected in April, May, and June 1940. Discharges were generally low during the periods from August 1939 to February 1940 and from December 1940 to February 1941. Medium high to high discharges prevailed from March to May 1940. Plates 26, 27, and 28 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results.

316. Monthly average dissolved oxygen results of 5 parts per million or less were observed in Reed Creek below Wytheville, Va.; in Crab Creek at Christiansburg, Va.; in Coal and Kanawha Rivers below St. Albans, W. Va.; in Armour Creek below Nitro, W. Va.; and in the Kanawha River below Winfield, W. Va. From 1 to 3 samples are represented in each average. Almost complete oxygen depletion was observed in Armour Creek below Nitro, where the dissolved oxygen content of a single sample collected in January 1940, was 0.5 parts per million.

317. Monthly average biochemical oxygen demand results of 5 parts per million or more, based on from 1 to 5 samples each, were observed in East Fork below Boone, N. C.; in Reed Creek below Wytheville, Va.; in Peak Creek below Pulaski, Va.; in Crab Creek at Christiansburg, Va., in Stroubles Creek below Blacksburg, Va.; in New River below Narrows, Va.; in Grassy Branch below Bluefield, Va.; in Little Buff Creek below West Jefferson, W. Va.; in Laurel Creek below Pocahontas, W. Va.; in Little Whitestick River below Beckley, W. Va.; and in the Kanawha River below Charleston, St. Albans, and Nitro, W. Va.

318. Average coliform bacteria counts agreed in general with dissolved oxygen and oxygen demand results in showing the extent of pollution. Highest values were observed below Wytheville, Charleston, Narrows, Chelyan, and Beckley, W. Va.

319. Acid stream conditions were observed in the vicinity of Pulaski, Va., on Peak Creek; and along Piney, Beaver, and Dunloup Creeks in the Beckley, W. Va., area. At Pulaski, stream acidity was due to chemical plant wastes, while at the other sampling stations, acidity was caused by mine drainage. Gas, oil, and refinery wastes produce taste and odor problems along Elk River.

320. Results of analyses for 53 sampling dates during the period August 1939 to April 1941 showed the dissolved oxygen content of the Kanawha River to be lower than that of the Ohio River above their junction on 48 of the sampling days. The biochemical oxygen demand and coliform bacteria content of the tributary were lower than those of the main stream about 59 percent and 73 percent of the sampling days, respectively.

321. *Methods of pollution control.*—The major pollution problems of the Kanawha River Basin are in the main stream in the vicinity of Charleston, where the rapidly growing chemical industry discharges large volumes of wastes which tax the oxygen resources of the stream and adversely affect downstream water supplies. It will be necessary to reduce the strength or quantity of these wastes if a further deterioration in the quality of the lower Kanawha River water is to be prevented. Because of constant changes in industrial processes, and their technical and often secret nature, pollution control in this area is largely the problem of the industries involved.

322. Primary domestic waste treatment is deemed sufficient to provide a desired degree of pollution abatement at Charleston, South Charleston, and 18 other communities along the main stream, and at 15 pollution sources on tributary streams. Secondary domestic waste treatment appears to be justified at Princeton, Richwood, and 14 other smaller communities on streams subject to near-zero summer flows. Supplemental treatment is necessary at 6 localities. Regulation of low flow by operation of proposed reservoirs would lower the

minimum sewage and industrial waste treatment requirements now indicated at pollution sources on the lower Kanawha River.

323. The cost of a suggested program of pollution control is shown in the following table. The program would eliminate local nuisance conditions, improve streams for use as public water supplies, and preserve and improve aquatic recreational facilities in the basin.

Suggested program of pollution control for the Kanawha River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatments:								
Primary	35	131,900	141,200	179,900	$1,520,000	$71,000	$108,000	$179,000
Secondary	16	32,500	42,800	52,600	860,000	40,000	61,000	101,000
Improvements	6	11,200	12,000		90,000	4,000	6,000	10,000
Subtotal	57	175,600	196,000		2,470,000	115,000	175,000	290,000
Interceptors					2,530,000	(1)	120,000	120,000
Industrial treatment	(2)				1,270,000	240,000	165,000	405,000
Mine sealing	(3)				120,000	13,000	5,000	18,000
Subtotal					6,390,000	368,000	465,000	833,000
Emergency allowance, 20 percent [4]					1,280,000			
Total					7,670,000			

[1] Negligible.
[2] Includes such items as minor corrections, process changes, sewer construction, treatment plants, etc.
[3] Initial program contemplates sealing of 2,170 ton-years of acid.
[4] Estimated additional cost of program if provided during present emergency period.

Appendix H

GUYANDOT RIVER BASIN

SUMMARY

324. *General description.*—The Guyandot River, which drains an area of 1,670 square miles, flows through the rugged, mountainous country of southwestern West Virginia and joins the Ohio River 305.2 river miles below Pittsburgh, Pa. Mud River is the important tributary. A general map of the basin is shown on plate 29.

325. Coal and gas deposits are the valuable natural resources and coal mining is the chief economic pursuit in the basin. Farming practiced is of a subsistence type only. The Guyandot River is not commercially navigable beyond the limits of slack water provided by Ohio River Dam No. 28. There are no hydroelectric power developments in the valley.

326. The population of the valley has increased about 140 percent since 1910, to a present total of approximately 148,300. About 95 percent of the total population is rural, and Logan and Mullens, with present populations of about 5,166 and 3,026, respectively, are the only urban communities. Many inhabitants live in mining

camps which are concentrated in the vicinity of Logan and in the extreme southeastern portion of the area.

327. *Water uses.*—There are 89 public water supplies in the Guyandot River Basin of which 17, aggregating 1.21 million gallons per day and serving about 22,200 persons, are from surface sources. Five of the latter supplies, which serve 12,900 people, come from streams subject to pollution. All of the communities using polluted surface sources practice chlorination; in addition, 4 communities employ coagulation, sedimentation, and filtration, and of these, 1 practices softening and iron removal. Two of the water supplies from unpolluted sources receive no treatment. Ground water is usually hard and is limited in quantity. A number of the communities use mine drainage as a source of public water supply.

328. No commercially developed recreational areas exist in the basin, although the Guyandot River and some of its tributaries are extensively used for fishing by local residents. Industrial water supply is not a major problem.

329. Low flow characteristics of the Guyandot River at two selected stream stations are as follows:

Stream	Guyandot River	
Location	Man, W. Va.	Branchland, W. Va.
Drainage area (square miles)	762	1,226
Period considered	1929–40	1929–40
June to September discharge (cubic feet per second):		
Minimum single month	10	15
Minimum 4-month average	29	41
Average	404	625

330. *Sources of pollution.*—About 23,900 persons, or 16 percent of the population of the basin, are served by sewers. No domestic sewage receives treatment. Much pollution reaches the streams of the basin from privies along the banks, and from other refuse that is dumped directly into the streams. A small cannery at Milton is the only industrial establishment in the basin which discharges an appreciable quantity of organic wastes. These wastes have a net population equivalent (based on biochemical oxygen demand) of about 200.

331. Most of the 25 coal washeries in the basin discharge fine coal particles which blanket the bottom of the streams and increase their turbidity. A power plant at Logan daily dumps ashes from about 900 tons of coal into the Guyandot River. Mine sealing has reduced the acid load to about 54 percent of the load carried prior to the inception of the sealing program. Present acid pollution from mine drainage approximates 10,865 tons per year (calcium carbonate equivalent).

332. *Extent of pollution.*—During the period from June 1939 to April 1940, the Public Health Service collected and analyzed more than 100 water samples from over 25 stream stations in the basin. Fifty-four percent of the samples were collected during November and December 1939. Average discharges on sampling days during the latter months were, on the whole, less than one-tenth of the mean summer-month discharge of record. In general, pollution problems

were found to be of a local nature. Plates 29, 30, and 31 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results.

333. Monthly average dissolved oxygen results, based on 1 to 5 samples each, were in excess of 6.5 parts per million with the exception of monthly averages of 4.9 and 5.3 parts per million which were observed at the mouth of the river during September and October 1940, respectively.

334. Monthly average biochemical oxygen demand results of 5 parts per million or more, based on 1 to 4 samples each, were observed in Winding Gulf Creek below Helen, in Island Creek below Omar, in Copperas Mine Fork below Holden, and at the mouth of both Island Creek and the Guyandot River.

335. Coliform bateria counts were in general agreement with oxygen demand results as to the location of major sources of pollution; these being below Helen, Mullens, Man, Omar, Holden, and Logan.

336. Acid stream conditions resulting from acid mine drainage were found in Island Creek and its tributary Copperas Mine Fork, where pH observations ranged from 4.5 to 5.2 and phenolphthalein acidities from about 20 to more than 200 parts per million.

337. Results of analyses for 35 sampling dates between June 1939 and April 1940 showed the Ohio River at dam No. 27, above the Guyandot River, to be of consistently better quality with respect to dissolved oxygen, biochemical oxygen demand, and coliform bacteria content than was the Guyandot River at a sampling station 0.1 mile above its mouth. Eight sets of samples disclosed the Guyandot River at a station 7.5 miles above its mouth to be similar in quality to the Ohio River at dam No. 27.

338. *Methods of pollution control.*—Results of water analyses indicate the effects of pollution in the Guyandot River Basin to be primarily local. At most localities, primary treatment of sewage would be sufficient to maintain good dissolved oxygen conditions. It would be desirable to intercept sewage from upstream communities whose wastes are now discharged to the Guyandot River above the water supply intake at Logan, for treatment with wastes from the latter community. Pollution from coal washeries is largely visual, and should not be difficult to correct. Continuation of the mine-sealing program will aid in reducing the mine acid load in tributary Island Creek Basin.

339. The cost of a suggested program of pollution control, including 13 primary municipal sewage-treatment plants, is shown in the following table. The program would eliminate local nuisance, improve streams for use as public water supplies, and preserve and improve aquatic recreational facilities.

Suggested program of pollution control for the Guyandot River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment: Primary (subtotal)	13	19,700	23,800		$300,000	$15,000	$20,000	$35,000
Interceptors					230,000	(1)	10,000	10,000
Mine sealing	(2)				10,000	1,000	1,000	2,000
Subtotal					540,000	16,000	31,000	47,000
Emergency allowance, 20 percent [3]					110,000			
Total					650,000			

[1] Negligible.
[2] Initial program contemplates sealing of 1,330 ton-years of acid.
[3] Estimated additional cost of program if provided during present emergency period.

Appendix I

BIG SANDY RIVER BASIN

SUMMARY

340. *General description.*—The Big Sandy River is formed by the confluence of Levisa and Tug Forks at the Kentucky-West Virginia border and flows north to join the Ohio River 317.1 river miles below Pittsburgh, Pa. About half of its drainage area of 4,280 square miles lies in Kentucky, and the remainder is almost equally divided between Virginia and West Virginia. The basin is rugged, and includes a relatively elevated section of the Appalachian Range. A general map of the basin is shown on plate 29.

341. Forests, principally of second growth hardwood, cover much of the basin surface; topography prohibits extensive agricultural activity; and manufacturing is of little significance in the area. Development of mineral resources, among which coal is of primary importance, constitutes the main economic activity of the basin. The navigation channel, provided by five locks and dams on the main stream and on the lower reaches of Levisa and Tug Forks, is little used except near the mouth of the Big Sandy River. There are no important hydroelectric developments.

342. The total population of the basin has more than doubled since 1910 and now approximates 411,900, of which about 8 percent is urban. Jenkins, Ky., and Williamson and Welch, W. Va., are the largest communities in the valley; their present populations are about 9,428, 8,366, and 6,264, respectively.

343. *Water uses.*—There are 120 public water supplies in the basin of which 18, aggregating about 2.99 million gallons per day and serving about 53,800 persons, are from surface sources. Fifteen of the surface supplies, which serve an aggregate of 44,300 persons, come from streams subject to pollution. Fourteen of the communities using water supplies subject to pollution practice coagulation, sedimentation, filtration, and chlorination and of these, 3 employ lime soda softening processes. No treatment is applied to the fifteenth surface source which is subject to pollution. Ground water supplies are limited in quantity and generally are of poor quality, being hard and often containing objectionable quantities of hydrogen sulfide. A number of communities use mine drainage as a source of public water supply.

344. Streams of the Big Sandy River Basin are used extensively by local residents for recreational purposes, but there are no commercial developments of this nature. Water supply for industry is not a major problem.

345. Low flow characteristics at a single station on Levisa Fork are as follows:

Stream	Levisa Fork
Location	Paintsville, Ky.
Drainage area (square miles)	2,150
Period considered	1929-40
June to September discharge (cubic feet per second):	
Minimum single month	26
Minimum 4-month average	85
Average	920

Discharges per unit of drainage area during periods of low flow have been greater in the Tug Fork Basin than in the Levisa Fork Basin.

346. *Sources of pollution.*—About 55,000 persons, or 13 percent of the population of the basin, are served by sewers. The only industrial establishment in the basin which discharges an appreciable quantity of organic wastes is a small meat packing plant at Paintsville, Ky. These wastes have a net population equivalent of about 400 (based on biochemical oxygen demand). In addition, there are 26 coal washeries which discharge varying amounts of fine coal particles. Of these, 17 recirculate wash waters and recover the fines removed by washing. Three secondary municipal waste treatment plants, in which about $70,000 have been invested, serve 2,600 persons and aid in reducing the combined population equivalent of domestic and industrial wastes to about 53,300 as discharged. A considerable amount of polluting matter reaches the streams from privies along the banks of the streams, and in the form of other refuse dumped directly into the streams. Some progress has been made with Works Progress Administration assistance in building sanitary privies.

347. Pollution from acid mine drainage now amounts to about 46,195 tons of acid per year (calcium carbonate equivalent). A reduction of about 25 percent in acid load has been effected by mine sealing since the inception of the program.

348. *Extent of pollution.*—During the period from June 1939 to April 1940 the Public Health Service collected and analyzed more than 350 water samples from over 85 stream stations in the basin. Sixty-seven percent of the samples were collected during October, November, and December, 1939. Average discharges on sampling days during November and December were much less than the mean summer-month flow of record. Plates 29, 30, and 31 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results.

349. Monthly average dissolve oxygen results below 5 parts per million, based on 1 to 3 samples each, were observed only in Holly Creek below Clintwood, Va., and in Paint Creek at Paintsville, Ky. With the exception of single monthly averages for Levisa Fork below Fort Gay, Ky., and for Big Sandy River below Louisa, Ky., and near the mouth, monthly average results, based on 1 to 11 samples each, were in excess of 6.5 parts per million.

350. Monthly average biochemical oxygen demand results in excess of 5 parts per million based on 2 to 4 samples each, were observed at several sampling stations on Tug Fork, Elkhorn Creek, Clear Fork, and Dry Fork in Tug Fork Basin, and at single stations on Holly Creek, Elkhorn Creek, Beaver Creek, Paint Creek, and Levisa Fork in the Levisa Fork Basin.

351. At approximately half of the sampling stations average coliform counts of more than 200 per milliliter were found, and at nearly 65 percent of the stations average coliform counts of over 50 per milliliter were observed. Highest values were recorded below Clintwood, Va.; Jenkinjones and Kimball, W. Va.; and Pikesville and Paintsville, Ky.

352. Acid stream conditions resulting from mine drainage were observed in Muddy Creek, a tributary of Levisa Fork, and along Mate Creek, a tributary of Tug Fork. Individual pH values ranged from 3.9 to 4.8 and phenolphthalein acidities from 39 to 164 parts per million. None of the larger streams of the basin were found to be acidic.

353. Results of water analyses for 96 sampling days during the period June 1939 to March 1940 showed the dissolved oxygen content of the Big Sandy River at a station 0.3 mile above its mouth to be consistently less than that of the Ohio River above their junction. The biochemical oxygen demand was higher and the coliform bacteria content was lower in the tributary than in the main stream on a majority of the sampling dates.

354. *Methods of pollution control.*—The two main streams of the Big Sandy Basin, Levisa, and Tug Forks, are not heavily polluted. Primary treatment of wastes discharged to these streams should be sufficient to maintain good oxygen conditions at all points except below Grundy, Va., on upper Levisa Fork, and below Welch, W. Va. on Tug Fork. Local nuisance conditions caused by the discharge of untreated sewage to a number of the tributary streams will require secondary treatment for their correction; however, considering the financial condition and lack of permanence of the communities involved, justification for expenditures beyond partial treatment is questionable. Elimination of largely visual pollution from coal washery wastes presents no particularly difficult technical problems.

355. The cost of a suggested program of pollution control, including 20 primary and 2 secondary municipal waste-treatment plants, is

shown in the following table. The program will minimize local nuisance conditions, improve streams for use as public water supplies, and preserve and improve the extensive aquatic recreational facilities of the basin.

Suggested program of pollution control for the Big Sandy River Basin—economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primary	20	36,600	51,000	57,000	$610,000	$29,000	$41,000	$70,000
Secondary	2	7,000	7,700	9,000	130,000	6,000	9,000	15,000
Subtotal	22	43,600	58,700		740,000	35,000	50,000	85,000
Interceptors					500,000	(1)	25,000	25,000
Mine sealing	(2)				240,000	26,000	10,000	36,000
Subtotal					1,480,000	61,000	85,000	146,000
Emergency allowance, 20 percent [3]					300,000			
Total					1,780,000			

[1] Negligible.
[2] Initial program contemplates sealing of 18,320 ton-years of acid.
[3] Estimated additional cost of program if provided during present emergency period.

Appendix J

SCIOTO RIVER BASIN

SUMMARY

356. *General description.*—The Scioto River Basin lies within Ohio and comprises 6,510 square miles in the central and south central portions of the State. The stream joins the Ohio River 356.5 river miles below Pittsburgh, Pa. The topography of the basin varies from flat areas to hilly sections, the latter of which are situated between Prospect and Columbus and from Chillicothe to the mouth. Principal tributaries are the Olentangy River and Big Walnut, Big Darby, Deer, Paint, and Salt Creeks. There is no commercial navigation nor important hydroelectric development. A general map of the basin is shown on plate 32.

357. Much of the Scioto River Basin is highly developed in agriculture. Canning, chemical, meat, metal, milk, paper, and miscellaneous other industries are also of considerable economic importance. Manufactured products include paper, shoes, hardware, tools, machinery, fertilizer, wool and wool fat products, cigars, glass, mattresses, rubber products, chemicals, mineral products, and others. Limestone is the most important mineral resource of the basin and much timber cover remains. The river is not commercially navigable beyond the limits of slack water induced by Ohio River navigation facilities.

358. Since 1910 rural population has remained practically unchanged in the area, but total population has increased about 35 percent and now approximates 739,600 of which 60 percent is urban. Columbus,

the basin's largest city, has 306,100 inhabitants; Marion has 30,800; and Chillicothe, 20,100.

359. *Water uses.*—There are 44 public water supplies in the basin. Five of the largest, aggregating about 32.66 million gallons per day and serving 350,200 persons, are from surface sources. About 96 percent of the total surface supply is used in the Columbus area; however, most pollution which originates above Columbus receives treatment. Two other surface water supply intakes are located below community sewer outfalls. In general, there is no serious pollution of public water supplies. All communities using surface waters practice coagulation, sedimentation, filtration, chlorination, and lime-soda softening. Ground-water supplies in the basin appear to be adequate and industrial water supply is not a major problem. There are some recreational developments on the Scioto River below Columbus.

360. Low flow characteristics at three selected stream stations in the basin are as follows:

Stream	Scioto River	Olentangy River	Paint Creek
Location	Chillicothe	Delaware	Bourneville
Drainage area (square miles)	3,847	387	808
Period considered	1921–40	1922–34	1924–40
June to September discharge (cubic feet per second):			
Minimum single month	214	1	11
Minimum 4-month average	305	7	25
Average	1,593	126	418

361. *Sources of pollution.*—A sewered population of about 412,600 and industrial wastes having a population equivalent of about 425,900 (based on biochemical oxygen demand), constitute the major pollution sources in the Scioto River Basin. Over 97 percent of the sewered domestic wastes receive treatment in 15 primary and 18 secondary plants, in which about $12,890,000 have been invested. Industrial wastes which have a population equivalent of 348,600 also receive municipal treatment. At least minor corrective measures have been taken by 33 of the 48 industrial plants not connected to municipal treatment. The combined domestic and industrial waste load, as discharged after treatment, has a population equivalent of approximately 251,400. Summarized data follow:

Waste sources:			
Total population (1940 census)			739, 551
Sewered population:			
Connected to municipal treatment		401, 500	
Not connected to municipal treatment		11, 100	
			412, 600
Industrial wastes (population equivalent, based on biochemical oxygen demand, after application of independent corrective measures now in force, but prior to other treatment):			
Connected to municipal treatment		348, 600	
Not connected to municipal treatment:			
Canning	32, 200		
Meat	2, 700		
Milk	700		
Paper	39, 200		
Miscellaneous	2, 500		
		77, 300	
			425, 900
Total (population equivalent)			838, 500

Wastes as discharged:		
Human wastes (sewered) (population equivalent after all present treatment):		
Connected to municipal treatment	62, 800	
Not connected to municipal treatment	11, 100	
		73, 900
Industrial wastes (population equivalent after all present treatment):		
Connected to municipal treatment	100, 200	
Not connected to municipal treatment	77, 300	
		177, 500
Total residual (population equivalent)		251, 400

NOTE.—Single industries of a specific classification are included within the miscellaneous classification.

362. Acid mine drainage, to the extent of about 17,870 tons of acid per year (calcium carbonate equivalent), also contributes to the pollution of the streams of the basin, but is of minor significance. A reduction of 26 percent in the initial acid load has been effected by mine sealing.

363. *Extent of pollution.*—The extent of stream pollution in the Scioto River Basin was determined by analysis of more than 1,490 water samples collected at over 80 stream sampling stations during 1939 and 1940. The stream reaches showing the greatest extent of pollution are the following:

(*a*) Scioto River, Columbus to mouth, a distance of 132 river miles: Samples in number from 9 to 17, collected at 12 stations during June 1939, showed average dissolved oxygen results from 3.0 to 6.5 parts per million, averaging 4.6 parts per million. Average discharge during the sampling period ranged from 2,680 cubic feet per second at Columbus to 8,390 cubic feet per second at the mouth, which flows are several times greater than mean summer discharges.

(*b*) Paint Creek below Washington Court House and below Greenfield: Average results for 2 samples collected during October 1939, at each of 5 stations in a 5-mile reach immediately below Washington Court House, showed dissolved oxygen results ranging from practically zero to 2.4 parts per million, and averaging 0.4 part per million. Discharge averaged 4 cubic feet per second at the time of sampling. For the same period, coliform bacteria counts averaged 180,000 per milliliter at the 5 stations below Washington Court House and 24,000 per milliliter below Greenfield. Single samples in October 1939, showed recovery from a dissolved oxygen content of almost zero to a content of 4.6 parts per million in a 16-mile reach above Greenfield, followed by almost complete oxygen depletion below Greenfield.

(*c*) Little Scioto River below Marion: Three samples collected at a single station during September and October 1939 showed an average dissolved oxygen content of 1.8 parts per million and an average coliform bacteria count of 38,600 per milliliter. Discharge averaged 1 cubic foot per second.

(*d*) Little Walnut Creek below Baltimore: Three samples collected at a single station during October and November 1939 showed an average dissolved oxygen content of 0.5 part per million, and an average coliform bacteria count of 2,730 per milliliter. Mean discharge was 2 cubic feet per second.

364. Plates 32, 33, and 34 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results for the Scioto River Basin.

365. The laboratory results for the basin indicate undesirable pollution along the Scioto River from Columbus to the mouth and in limited reaches of Paint, Little Scioto, and Little Walnut Creeks. These latter are primarily local problems. Except as noted, dissolved oxygen averages were generally above 6.5 parts per million. In spite of extensive control measures now in effect at Columbus, surface wash resulting from local rains is at times sufficient to result in oxygen depletion in the Scioto River below the city.

366. Analytical results for samples collected on 18 sampling days during the period September 1939 to January 1940 showed the Scioto River at Lucasville Bridge (river mile 15) to have a dissolved oxygen content consistently less than that of the Ohio River at dam No. 31, above their junction. Coliform bacteria counts for the tributary were consistently lower than those for the Ohio River, while biochemical oxygen demand results were somewhat higher.

367. *Methods of pollution control.*—The cost of a suggested program of pollution control is shown in the following table. The program would eliminate local nuisance conditions which now exist and would restore streams for recreational use, particularly in headwater areas. However, improved industrial waste treatment technique will be required to fully control pollution in the Chillicothe and Circleville areas.

368. Periodic flow augmentation would be effective in eliminating occasional nuisance conditions below Columbus and could be obtained by drawing from the small Whittier Street Reservoir on the Scioto River in the city. A dependable water supply for the purpose of replenishing the Whittier Street pool could be provided by the proposed Delaware flood control reservoir.

Suggested program of pollution control for the Scioto River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primary	18	4,600	12,800	16,900	$240,000	$11,000	$18,000	$29,000
Secondary	4	6,500	11,500	13,000	200,000	10,000	15,000	25,000
Improvements	8	19,800	27,100		230,000	9,000	17,000	26,000
Subtotal	30	30,900	51,400		670,000	30,000	50,000	80,000
Interceptors					260,000	(1)	10,000	10,000
Industrial treatment	(2)				370,000	40,000	50,000	90,000
Mine sealing	(3)				40,000	4,000	2,000	6,000
Improvements to Whittier St. dam					(1)	(1)	(1)	(1)
Low flow control					(4)	(4)	(4)	(4)
Subtotal					1,340,000	74,000	112,000	186,000
Emergency allowance; 20 percent [5]					270,000			
Total					1,610,000			

[1] Negligible.
[2] Includes such items as minor corrections, process changes, sewer construction, treatment plants, etc.
[3] Initial program contemplates sealing of 7,100 ton-years of acid.
[4] Negligible; incidental to flood control if provided.
[5] Estimated additional cost of program if provided during present emergency period.

Appendix K

LITTLE MIAMI RIVER BASIN

SUMMARY

369. *General description.*—The Little Miami River joins the Ohio River 464.1 river miles below Pittsburgh, Pa. Its basin comprises 1,755 square miles situated in a glaciated region wholly within southwestern Ohio, and constitutes a broad plateau, ranging in elevation from about 900 to about 1,200 feet above mean sea level. Principal tributaries are Caesar Creek and Todd and East Forks. A general map of the basin is shown on plate 35.

370. There are no hydroelectric developments or outstanding mineral resources in the basin, and timber cover has been largely removed. Ohio River Dam No. 37 provides slack water in the lower mile of the stream. Fertile soil and climatic conditions favor agriculture, and agriculture and canning are the most important economic pursuits. Industrial development has begun on the lower reaches of the stream, adjacent to the Cincinnati metropolitan area, and the proximity of the basin to population centers has resulted in its extensive use for recreational purposes.

371. Xenia, with about 10,630 inhabitants (1940 census) is the largest city in the basin. Total population, exclusive of the Cincinnati metropolitan area, approximates 135,500, and is about 82 percent rural. Both urban and rural population have increased about 15 percent since 1910.

372. *Water uses.*—There are 21 public water supplies in the basin of which 4, serving about 3,200 persons and aggregating 0.16 million gallons per day, are from surface sources, in all cases tributary to the main stream. Coagulation, sedimentation, filtration, and chlorination are applied to all surface supplies. Most communities use ground water which is limited in quantity in many sections, and generally hard, with high iron content. With the exception of Batavia and Williamsburg, surface water supplies are located above community sewer outfalls and are not seriously affected by pollution. The prevalence of stock watering and an increasing public demand for aquatic recreational facilities appear to warrant the application of high standards of stream quality. In addition, the inadequacy of ground water supplies indicates possible increased future public use of water from surface sources. Industrial water supply is not a major problem.

373. Low flow characteristics at two stream stations in the basin follow:

Stream	Little Miami River	East Fork Little Miami River
Location	Milford	Perintown
Drainage area (square miles)	1,195	477
Period considered	1924–39	1914–39
June to September discharge (cubic feet per second):		
Minimum single month	70	1
Minimum 4-month average	107	5
Average	683	268

374. *Sources of pollution.*—About 109,700 persons, of which 78,000 are situated in Cincinnati and its suburban areas, are served by sewers. Industrial wastes having a population equivalent of 60,700 (based on biochemical oxygen demand), of which 51,000 is from the Cincinnati area, are discharged to the streams of the basin. Exclusive of the Cincinnati industrial waste load, 4 of the 10 canneries contributing the remaining industrial load have taken steps to reduce the strength of their wastes, and 2 vegetable canneries discharge wastes, having a 2,800 total population equivalent, to municipal treatment plants. Three primary and 8 secondary municipal treatment plants in which about $530,000 have been invested serve 8,100 and 16,500 persons, respectively. These aid in reducing the combined population equivalent of domestic and industrial wastes to about 149,100 as discharged to streams. Summarized data follow:

Waste sources:			
Total population (1940 census):			
Cincinnati and suburbs (Little Miami River portion)	81, 000		
Remainder of Little Miami River Basin	135, 474		
		216, 474	
Sewered population:			
Connected to municipal treatment:			
Cincinnati and suburbs (Little Miami River portion)	0		
Remainder of Little Miami River Basin	24, 600		
		24, 600	
Not connected to municipal treatment:			
Cincinnati and suburbs (Little Miami River portion)	78, 000		
Remainder of Little Miami River Basin	7, 100		
		85, 100	
			109, 700
Industrial wastes (population equivalent after application of independent corrective measures now in force but prior to other treatment):			
Connected to municipal treatment:			
Cincinnati and suburbs (Little Miami River portion)	0		
Remainder of Little Miami River Basin	2, 800		
		2, 800	
Not connected to municipal treatment:			
Cincinnati and suburbs (Little Miami River portion)	51, 000		
Remainder of Little Miami River Basin	6, 900		
		57, 900	
			60, 700
Total (population equivalent)			170, 400
Wastes as discharged:			
Human wastes (sewered) (population equivalent after all present treatment):			
Connected to municipal treatment:			
Cincinnati and suburbs (Little Miami River portion)	0		
Remainder of Little Miami River Basin	4, 700		
		4, 700	
Not connected to municipal treatment:			
Cincinnati and suburbs (Little Miami River Basin portion)	78, 000		
Remainder of Little Miami River Basin	7, 100		
		85, 100	
			89, 800

Wastes as discharged—Continued			
Industrial wastes (population equivalent after all present treatment):			
Connected to municipal treatment:			
Cincinnati and suburbs (Little Miami River Basin portion)	0		
Remainder of Little Miami River Basin	1, 400		
		1, 400	
Not connected to municipal treatment:			
Cincinnati and suburbs (Little Miami River Basin portion)	51, 000		
Remainder of Little Miami River Basin	6, 900		
		57, 900	
			59, 300
Total waste residual (population equivalent)			149, 100

375. *Extent of pollution.*—The Public Health Service collected and analyzed more than 400 water samples from over 35 stream stations in the basin during the period January 1939, to April 1940. Sampling dates were well distributed throughout the period. Reaches showing the greatest extent of pollution are the following:

(*a*) Little Miami River: A single sample collected above South Charleston in September 1939, had a dissolved oxygen content of 4.0 parts per million. Other dissolved oxygen results for the main stream averaged uniformly above 5 parts per million, except below Beechmont Bridge in the Cincinnati metropolitan area, where 4 samples in October and November 1939, had an average dissolved oxygen content of 2.8 parts per million, biochemical oxygen demand of 7.0 parts per million, and a coliform bacteria count of 4,600 per milliliter.

(*b*) Caesar Creek below Jamestown: Two samples in August 1939, had an average dissolved oxygen content of 2.5 parts per million; a third, collected in October 1939, contained 3.4 parts per million. Flows averaged about 1 cubic foot per second on the sampling dates.

(*c*) Lyttle Creek above and below Wilmington: Samples in the latter months of 1939 showed severe oxygen depletion, high biochemical oxygen demand, and high coliform bacteria counts. Flows were low.

(*d*) Turtle Creek below Lebanon: From 1 to 3 samples in each month from July 1939, to January 1940, with the exception of December 1940, showed average dissolved oxygen results ranging from zero to 5.0 parts per million, biochemical oxygen demands ranging from 2.4 to 46.0 parts per million, and coliform bacteria counts as high as 240,000 per milliliter, and not less than 1,580 per milliliter.

376. Laboratory results for water samples collected on 23 days between March 1939, and April 1940, showed the dissolved oxygen content of the Little Miami River at Beechmont Bridge (river mile 4.3) to be consistently less than that of the Ohio River above their junction. The biochemical oxygen demand and coliform bacteria content of the tributary were consistently higher than those of the main stream. During the same period, the Little Miami River above the Cincinnati metropolitan area was similar in quality to the Ohio River above their junction.

377. Plates 35, 36, and 37 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results for the Little Miami River Basin.

378. *Methods of pollution control.*—Pollution problems in the Little Miami River Basin are minor, generally of local significance, and can

be satisfactorily solved by waste treatment. The cost of a suggested program of pollution control is shown in the following table. The program would eliminate local nuisance, protect valuable aquatic recreational facilities, and improve streams in anticipation of further use for public water supply.

Suggested program of pollution control for the Little Miami River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primary	3	2,900	5,000	5,500	$70,000	$3,000	$7,000	$10,000
Secondary	8	4,200	6,000	6,800	230,000	10,000	16,000	26,000
Improvements	3	19,100	20,500		110,000	3,000	6,000	9,000
Subtotal	14	26,200	31,500		410,000	16,000	29,000	45,000
Interceptors					120,000	(1)	5,000	5,000
Industrial treatment	(2)				50,000	4,000	6,000	10,000
Subtotal					580,000	20,000	40,000	60,000
Emergency allowance, 20 percent [3]					120,000			
Total					700,000			

[1] Negligible.
[2] Includes such items as minor corrections, process changes, sewer construction, treatment plants, etc.
[3] Estimated additional cost of program if provided during present emergency period.

Appendix L

LICKING RIVER BASIN

SUMMARY

379. *General description.*—The Licking River joins the Ohio River opposite Cincinnati, Ohio, 470.2 river-miles below Pittsburgh, Pa. The basin of the Licking River comprises 3,670 square miles situated wholly within Kentucky, and is mainly hilly and mountainous. The basin also includes a portion of the blue-grass region. Principal tributaries are the North and South Forks. A general map of the area is shown on plate 38.

380. The Licking River Basin is predominately rural, and, outside of the area at its mouth, agriculture is the principal economic pursuit. There are attractive hydroelectric power reservoir sites in the basin, and the main river is navigable to a point about 3 miles above its mouth. Timber resources are almost exhausted, mineral resources include coal, oil, iron ore, sandstone, and fire clays, none of which are extensively worked.

381. The population of the valley has remained virtually unchanged since 1910, and now approximates 170,100 of which about 15 percent is urban. Winchester, Paris, Cynthiana, and Mount Sterling are the principal communities. Their populations are, respectively, 8,594,

6,697, 4,840, and 4,782 (1940 census). All 4 are located in the tributary South Fork area.

382. *Water uses.*—There are 17 public water supplies in the basin of which 13, aggregating about 2.56 million gallons per day and serving 36,200 persons, are from surface sources. Five of the latter are situated below sources of sewage pollution; however, only 2 of these, serving a total of 5,400 persons, are seriously affected. Coagulation, sedimentation and chlorination are practiced by all communities using surface waters, and 10 supplies are filtered.

383. There are no outstanding recreational developments in the basin, but its streams are used for fishing and bathing by local residents. There is no industrial water-supply problem.

384. Low-flow characteristics at two stream stations in the basin are as follows:

Stream	Licking River	South Fork, Licking River
Location	Catawba, Ky.	Hayes, Ky.
Drainage area (square miles)	3,320	922
Period considered	1928–40	1928–31
June to September discharge (cubic feet per second):		
Minimum single month	12	0
Minimum 4-month average	34	4
Average	1,716	503

385. *Sources of pollution.*—About 25,200 persons, or 15 percent of the population of the basin, are served by sewers. Industrial wastes from 7 small establishments have an additional net population equivalent of 3,300 (based on biochemical oxygen demand) after application of various corrective measures in 5 of the establishments. None of the industrial wastes receive municipal treatment. Two secondary municipal sewage treatment plants, in which about $290,000 have been invested, serve 11,200 persons and aid in reducing the net population equivalent of domestic and industrial wastes to about 18,900, as discharged. Pollution by acid mine drainage is of little significance. Summarized data follow:

Waste sources:			
Total population (1940 census)			170,143
Sewered population:			
Connected to municipal treatment		11,200	
Not connected to municipal treatment		14,000	
			25,200
Industrial wastes (population equivalent, based on biochemical oxygen demand, after application of independent corrective measures now in force, but prior to other treatment):			
Connected to municipal treatment		0	
Not connected to municipal treatment:			
Meat	400		
Milk	300		
Miscellaneous	2,600		
		3,300	
			3,300
Total (population equivalent)			28,500

Wastes as discharged:		
Human wastes (sewered) (population equivalent after all present treatment):		
Connected to municipal treatment	1, 600	
Not connected to municipal treatment	14, 000	
		15, 600
Industrial wastes (population equivalent after all present treatment):		
Connected to municipal treatment	0	
Not connected to municipal treatment	3, 300	
		3, 300
Total waste residual (population equivalent)		18, 900

NOTE.—Single industries of a specific classification are included within the miscellaneous classification.

386. *Extent of pollution.*—The Public Health Service collected and analyzed more than 260 water samples from over 45 stream stations in the basin during the period from February 1939 to March 1940. Sampling dates were well distributed throughout these months. In general, pollution problems appeared to be of a local nature. Reaches showing the greatest evidence of pollution are as follows:

(*a*) Triplett Creek below Morehead: Three samples collected in September and October 1939 had an average dissolved oxygen content of 2.5 parts per million, biochemical oxygen demand of 4.3 parts per million, and coliform bacteria count of 528 per milliliter. Stream discharge was low.

(*b*) Hinkston Creek below Mount Sterling: Five samples collected in September and October 1939 showed complete oxygen depletion, an average biochemical oxygen demand of 31.6 parts per million, and an average coliform bacteria count of 84,400 per milliliter, at low flow.

(*c*) Hinkston Creek below Millersburg: Four samples collected in September and October 1939, had an average dissolved oxygen content of 2.6 parts per million, biochemical oxygen demand of 2.9 parts per million, and coliform bacteria count of 73 per milliliter.

(*d*) Brush Fork and Scrub Grass Creek at Carlisle: Single samples from each stream showed an average dissolved oxygen content of 3.0 parts per million and biochemical oxygen demand of 16.4 parts per million.

(*e*) Strodes Creek in the vicinity of Winchester: The averages for from 2 to 5 samples at each of 3 sampling stations showed the dissolved oxygen content to range from 1.0 to 3.5 parts per million.

(*f*) Stoner Creek below Paris: Complete oxygen depletion was noted in 3 samples in September and October 1939. Biochemical oxygen demand averaged 44.9 parts per million, the average coliform bacteria count approximated 46,000 per mililiter. Flows were low.

387. Partial oxygen depletion was also noted in the South Fork below Cynthiana. However, with the exception of the noted localities, dissolved oxygen results generally averaged in excess of 6.5 parts per million, and biochemical oxygen demand less than 3 parts per million. Observed pH values were consistently above 7.0.

388. Analytical results for 20 sampling days during the period April to December 1939 showed the dissolved oxygen content of the Licking River at river mile 3.3 (April to June) and at river mile 5.5 (June to December) to be consistently less than that of the Ohio River above their junction. Biochemical oxygen demand and coliform bacteria results were similar for the tributary and the main river.

389. Plates 38, 39, and 40 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results for the Licking River Basin.

390. *Methods of pollution control.*—Because of the low summer flows experienced in the Licking River Basin, need for secondary waste treatment is indicated at numerous communities. However, problems are generally local in nature and readily amenable to solution. Low flow control does not appear to be an economically attractive substitute for conventional waste treatment methods.

391. The cost of a suggested program of pollution control is shown in the following table. The program will eliminate local nuisance conditions, improve the streams for use as sources of public water supply, and preserve and improve recreational facilities.

Suggested program of pollution control for the Licking River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primary	2	1,200	2,500	2,800	$40,000	$1,500	$2,500	$4,000
Secondary	11	12,800	20,100	23,800	420,000	20,000	30,000	50,000
Improvements	1	6,300	9,000		60,000	2,500	3,500	6,000
Subtotal	14	20,300	31,600		520,000	24,000	36,000	60,000
Interceptors					180,000	(1)	8,000	8,000
Industrial treatment	(2)				10,000	1,000	1,000	2,000
Subtotal					710,000	25,000	45,000	70,000
Emergency allowance, 20 percent [3]					140,000			
Total					850,000			

[1] Negligible.
[2] Includes such items as minor corrections, process changes, sewer construction, treatment plants, etc.
[3] Estimated additional cost of program if provided during present emergency period.

Appendix M

MIAMI RIVER BASIN

SUMMARY

392. *General description.*—The Miami River drains an area of 5,385 square miles, about three-fourths of which is situated in southwestern Ohio. The remainder of the area is in southeastern Indiana. The stream joins the Ohio River 491.1 river miles below Pittsburgh, Pa. The topography of its basin varies from gently rolling areas to hilly sections. Upland elevations range from about 800 to about 1,100 feet above mean sea level. The Whitewater, Stillwater, and Mad Rivers are important tributaries. A general map of the area is shown on plate 35.

393. Natural resources include tillable soil, limestone, sand, gravel, and abundant ground water; however, the basin is singularly barren of essential raw materials necessary to the operation of the diversified industry located within its boundaries. Hydroelectric power is pro-

duced on a small scale, but large scale development does not appear to be economically attractive. The river is regarded as navigable to the head of beneficial slack water provided by Ohio River Dam No. 38.

394. The basin as a whole is well developed, both agriculturally and industrially. Manufactured products include paper, machinery, tools, automobile parts, sheet metal, metal products, textiles, canned foods, and dairy products. Paper manufacturing is the largest industry.

395. Both urban and rural populations have increased rapidly in the last several decades, and the total population of the basin now approximates 830,500 of which about 60 percent is urban. The larger cities, together with their populations (1940 census), are as follows:

Dayton, Ohio	210, 718	Hamilton, Ohio	50, 592
Springfield, Ohio	70, 662	Richmond, Ind	35, 147

396. *Water uses.*—There are 64 public water supplies in the basin of which 5, serving 101,300 persons and aggregating 12.51 million gallons per day are from surface sources. The remainder are from ground water sources which appear to be plentiful and of good chemical quality. All surface supplies are chlorinated and 3 are lime-soda softened. The supplies at Greenville and Piqua are located below community sewer outfalls and thus are subject to pollution. In general, pollution does not seriously affect other public water supplies. However, an increasing public demand for improved aquatic recreational facilities and possible augmented use of surface water in the future appear to warrant maintenance of high standards of stream quality. Industrial water supply is of some importance but does not present a major problem.

397. Low flow characteristics at two selected stream stations in the basin are as follows:

Stream	Miami River	Mad River
Location	Hamilton, Ohio	Dayton, Ohio
Period considered	1910-40	1914-39
Drainage area (square miles)	3,639	632
June to September discharge (cubic feet per second):		
Minimum single month	335	125
Minimum 4-month average	465	145
Average	1, 746	466

398. *Sources of pollution.*—Pollution of the Miami River is typical of a highly developed and industrialized area. Sewage from 550,500 persons, in 64 communities, and industrial wastes having an approximate population equivalent of 401,500 (based on biochemical oxygen demand), after application of various minor corrective measures by industry, are the principal pollutants. About 333,400 persons are serviced by secondary treatment in 21 communities, and 10 municipalities provide primary treatment for a total of 89,000 persons. A total of about $9,380,000 have been invested in these facilities. Industrial wastes with an approximate population equivalent of 166,200 are also connected to municipal treatment, and at least minor

corrective measures have been taken at 40 of the 89 remaining industrial pollution sources of significance. Summarized data follow:

Waste sources:			
Total population (1940 census)			830,481
Sewered population:			
Connected to municipal treatment		422,400	
Not connected to municipal treatment		128,100	
			550,500
Industrial wastes (population equivalent, based on biochemical oxygen demand, after application of independent corrective measures now in force, but prior to other treatment):			
Connected to municipal treatment		166,200	
Not connected to municipal treatment:			
Brewing	1,700		
Canning	26,800		
Meat	3,200		
Milk	1,500		
Paper	167,000		
Miscellaneous	35,100		
		235,300	
			401,500
Total (population equivalent)			952,000
Wastes as discharged:			
Human wastes (sewered) (population equivalent after all present treatment):			
Connected to municipal treatment			88,700
Not connected to municipal treatment			128,100
			216,800
Industrial wastes (population equivalent after all present treatment):			
Connected to municipal treatment		30,600	
Not connected to municipal treatment		235,300	
			265,900
Total waste residual (population equivalent)			482,700

NOTE.—Single industries of a specific classification are included within the miscellaneous classification.

399. Nineteen metallurgical industries discharge approximately 6,875 tons of acid pickling liquor per year (calcium carbonate equivalent) into the streams of the basin.

400. *Extent of pollution.*—The Public Health Service collected and analyzed over 975 water samples from more than 75 stream stations during the period from February 1939 to April 1940. Reaches showing the greatest extent of pollution are the following:

(*a*) Miami River below Dayton, Ohio: One or more monthly averages, each based on from 2 to 5 samples, collected at each of 7 stations between Dayton and Hamilton, Ohio, during the period August to October 1939, had dissolved oxygen contents ranging from 4.0 to 5.0 parts per million. Corresponding biochemical oxygen demand values ranged from 4.6 to 8.6 parts per million. Coliform bacteria counts were uniformly high. On the sampling dates, flows averaged somewhat less than mean summer discharge.

(*b*) Jacket Creek below Bellefontaine, Ohio: Two samples in September 1939 showed complete oxygen depletion and an average biochemical oxygen demand of 36.6 parts per million. Coliform bacteria counts averaged 175,000 per milliliter. Flow averaged 34 cubic feet per second.

401. Single monthly averages, each based on from 1 to 3 samples, also showed dissolved oxygen of 5 parts per million or less in Buckangahelas Creek above De Graff, Ohio; in the East Fork of Whitewater River above Richmond, Ind.; in Dismal Creek below Union City, Ohio; in Greenville Creek below Greenville, Ohio; and in Stillwater River below Covington, Ohio. Monthly average biochemical oxygen demand results in excess of 5 parts per million were observed throughout the length of the Miami River, and on tributaries below pollution sources.

402. Laboratory results for 67 sampling dates during the period March 1939 to April 1940 showed the dissolved oxygen content of the Miami River, 4.2 miles from the mouth, to be higher than that of the Ohio River above their junction about 55 percent of the sampling days. The biochemical oxygen demand of the tributary was higher than that of the Ohio River about 87 percent of the time, and the coliform bacteria count was lower on about 67 percent of the sampling days.

403. Plates 35, 36, and 37 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results for the Miami River Basin.

404. *Methods of pollution control.*—Limitations in existing, practical methods of industrial waste treatment are controlling factors in abatement of pollution in certain stream reaches in the basin. Other pollution problems are readily amenable to solution by waste treatment. Low flow regulation offers little promise as an economic method of pollution control although its provision as an incidental feature of flood-control development would be desirable.

405. The cost of a suggested pollution control program is shown in the following table. The program would eliminate local nuisances, improve aquatic recreational facilities, improve streams for use as water supplies, and establish satisfactory stream quality in anticipation of extended public use.

Suggested program of pollution control for the Miami River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primary	7	99, 200	100, 000	108, 700	$820, 000	40, 000	$58, 000	$98, 000
Secondary	18	28, 000	39, 000	50, 300	820, 000	40, 000	58, 000	98, 000
Improvements	7	71, 000	86, 700		480, 000	15, 000	34, 000	49, 000
Subtotal	32	198, 200	225, 700		2, 120, 000	95, 000	150, 000	245, 000
Interceptors					1, 560, 000	(1)	75, 000	75, 000
Industrial treatment	(2)				1, 180, 000	185, 000	155, 000	340, 000
Subtotal					4, 860, 000	280, 000	380, 000	660, 000
Emergency allowance, 20 percent [3]					970, 000			
Total					5, 830, 000			

[1] Negligible.
[2] Includes such items as minor corrections, process changes, sewer construction, treatment plants, etc.
[3] Estimated additional cost of the program if provided during present emergency period.

Appendix N

KENTUCKY RIVER BASIN

SUMMARY

406. *General description.*—The Kentucky River Basin lies within, and comprises about one-sixth of the area of Kentucky. It drains 6,940 square miles and joins the Ohio River 545.8 river miles below Pittsburgh, Pa. The headwater regions are rugged and mountainous, the middle area is characterized by isolated hills, and downstream areas are primarily fertile tableland. Principal tributaries include Eagle and Elkhorn Creeks, Dix and Red Rivers, and North, Middle, and South Forks. A general map of the area is shown on plate 38.

407. The river is now canalized to river mile 258.6, the extent of the main stream. The further development of hydroelectric power in the area offers attractive possibilities. Economically important mineral resources of the basin are coal, petroleum, phosphate rock, building stone, calcite, barite, fluorspar, galena, sphalerite, cement rock, and oil shale. Coal mining of national importance and agriculture are the principal economic pursuits. Much of the food crops are processed in the basin, and the distilling industry, which produces about 10,000,000 gallons of whisky annually, is of considerable importance.

408. The population of the valley has increased about 35 percent since 1910, and now approximates 482,000 of which about 20 percent is urban. Lexington, the largest city, has about 49,300 inhabitants, and, with the exception of Frankfort, which has about 11,490, no other community in the basin has as many as 10,000 inhabitants.

409. *Water uses.*—There are 38 public water supplies in the basin of which 19, aggregating about 10.27 million gallons per day and serving 132,800 persons, are from surface sources. Although 10 surface water supplies serving 113,300 persons are obtained from below sources of pollution, only at Irvine are the effects of pollution serious. Chlorination is practiced by all communities using surface waters, 18 supplies are coagulated and settled, and 16 of the latter are filtered. The supply at Berea is chlorinated only. Ground water is available generally, but in limited quantities only, and its chemical quality is usually poor.

410. Recreational activities such as swimming, boating, and fishing are extensive on the Kentucky River and many of its tributaries. Industrial water supply is not a major problem.

411. Low flow characteristics of the Kentucky River at two selected stream stations are as follows:

Stream	Kentucky River	
Location	Winchester	Frankfort
Drainage area (square miles)	3,960	5,400
Period considered	1909-40	1925-40
June to September discharge (cubic feet per second):		
Minimum single month	16	91
Minimum 4-month average	83	147
Average	1,967	3,058

412. *Sources of pollution.*—About 105,300 persons, or 22 percent of the population of the basin, are served by sewers. Industries, after application of various corrective measures, contribute wastes having an additional population equivalent of 131,400 (based on biochemical oxygen demand), of which 32,900 receives further treatment in municipal plants. Of the 23 industrial establishments whose wastes do not receive municipal treatment, 9 distilleries account for about 90 percent of the total waste load. Fifteen industrial establishments, including all of the distilleries, have taken at least minor corrective measures toward reducing their pollution of the streams. Three primary and 10 secondary municipal waste treatment plants, in which about $1,370,000 have been invested, serve 1,200 and 68,200 persons, respectively, and aid in reducing the combined population equivalent of domestic and industrial wastes to about 150,400, as discharged. Summarized data follow:

Waste sources:			
Total population (1940 census)			481, 969
Sewered population:			
Connected to municipal treatment		69, 400	
Not connected to municipal treatment		35, 900	
			105, 300
Industrial wastes (population equivalent after application of independent corrective measures now in force but prior to other treatment):			
Connected to municipal treatment		32, 900	
Not connected to municipal treatment:			
Canning	6, 300		
Distilling	86, 200		
Meat	1, 100		
Milk	1, 000		
Miscellaneous	3, 900		
		98, 500	
			131, 400
Total (population equivalent)			236, 700
Wastes as discharged:			
Human wastes (sewered) (population equivalent after all present treatment):			
Connected to municipal treatment		11, 100	
Not connected to municipal treatment		35, 900	
			47, 000
Industrial wastes (population equivalent after all present treatment):			
Connected to municipal treatment		4, 900	
Not connected to municipal treatment		98, 500	
			103, 400
Total waste residual (population equivalent)			150, 400

NOTE.—Single industries of a specific classification are included within the miscellaneous classification.

413. Acid mine drainage causes problems of primarily local importance in the area drained by the North Fork. Mine sealing has reduced the acid load carried by the streams prior to the inception of the sealing program by about 30 percent. The present acid load is about 30,470 tons per year (calcium carbonate equivalent).

414. *Extent of pollution.*—The Public Health Service collected and analyzed more than 260 water samples from more than 80 stream stations, during the period March 1939 to January 1941. Seventy-four percent of these samples were collected in September, October,

and November, 1939. In general, discharges on the sampling dates during the latter period were less than the mean summer discharges of record. Pollution problems in the basin appear to be of a local nature. Typical of such problems are the following:

(*a*) North Fork Kentucky River below Hazard: Single samples taken at 3 points below Hazard, during October 1939 had dissolved oxygen contents ranging from zero to 3.3 parts per million, and averaging 1.1 parts per million; biochemical oxygen demand results ranging from 8.8 to 106.2 parts per million, and averaging 67.3 parts per million; and coliform bacteria counts ranging from 4,600 to 110,000 per milliliter. Discharge averaged about 1 cubic foot per second. Two samples collected at a station 21 miles downstream showed an average dissolved oxygen content of 10.2 parts per million, biochemical oxygen demand of 1.7 parts per million, and coliform bacteria count of 5 per milliliter.

(*b*) North Fork Elkhorn Creek below Georgetown: Two samples collected in September and October, 1939, at a station 1 mile below Georgetown had an average dissolved oxygen content of 2.2 parts per million, biochemical oxygen demand of 20.8 parts per million, and coliform bacteria count of 48 per milliliter. Flows were low.

415. Partial or complete oxygen depletion was also observed in Wright Fork at McRoberts, North Fork below Whitesburg, Goose Creek above Manchester, Dreaming Creek below Richmond, Silver Creek and Walnut Meadow Branch below Berea, Town Branch below Nicholasville, St. Asaph Creek below Stanford, Town Branch below Lancaster, Clark Run and Town Branch below Danville, Penitentiary Run at mouth, Kentucky River below Frankfort, Town Branch below Lexington, and South Fork Elkhorn Creek below the Narcotic Farm. With the exception of local areas, dissolved oxygen results during the sampling period were generally above 6.5 parts per million, and biochemical oxygen demand results less than 3 parts per million.

416. Laboratory results for 55 sampling dates during the period March 1939 to January 1941 showed the dissolved oxygen content of the Kentucky River at the mouth to be higher than that of the Ohio River above their junction, on half of the sampling days. The biochemical oxygen demand and coliform bacteria content of the tributary were less than those observed in the main stream on about 75 percent of the sampling days.

417. Plates 38, 39, and 40 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results for the Kentucky River.

418. *Methods of pollution control.*—Abatement of pollution in the Kentucky River Basin presents no difficult technical problems. The cost of a suggested pollution-control program is shown in the following table. The program would eliminate local nuisance conditions, protect existing surface water supplies from upstream pollution, and improve surface waters for extended recreational and water supply use.

Suggested program of pollution control for the Kentucky River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primary	3	18,200	20,000	24,300	$210,000	$9,000	$14,000	$23,000
Secondary	7	17,500	20,800	23,300	370,000	20,000	25,000	45,000
Improvements	3	47,700	51,700		90,000	1,000	6,000	7,000
Subtotal	13	83,400	92,500		670,000	30,000	45,000	75,000
Interceptors					460,000	(1)	25,000	25,000
Industrial treatment	(2)				360,000	5,000	55,000	60,000
Mine sealing	(3)				130,000	14,000	5,000	19,000
Subtotal					1,620,000	49,000	130,000	179,000
Emergency allowance, 20 percent [4]					320,000			
Total					1,940,000			

[1] Negligible.
[2] Includes such items as minor corrections, process changes, sewer construction, treatment plants, etc.
[3] Initial program contemplates sealing of 9,520 ton-years of acid.
[4] Estimated additional cost of program if provided during present emergency period.

Appendix O

SALT RIVER BASIN

SUMMARY

419. *General description.*—The Salt River Basin lies within the bluegrass area of north central Kentucky. The stream drains 2,890 square miles and joins the Ohio River 629.9 river miles below Pittsburgh, Pa. Floyd and Rolling Forks are principal tributaries. A general map of the basin is shown on plate 38.

420. There are no flood control or hydroelectric power developments in the basin, and the river is not commercially navigable except for slack water provided in its lower reach by Ohio River Dam No. 43. The valley is fertile and almost entirely under cultivation. Distilling is the principal industry.

421. Since 1910 the population of the basin has increased about 10 percent, to a present figure of approximately 139,900 of which about 11 percent is urban. Harrodsburg, the basin's largest city, has about 4,673 inhabitants. Only 3 other communities have as many as 3,000 inhabitants. These are Shelbyville, 4,392; Lebanon, 3,786; and Bardstown, 3,152.

422. *Water uses.*—There are 17 public water supplies in the basin of which 15, aggregating about 2.06 million gallons per day and serving 26,500 persons, are from surface sources. Five of the latter, which serve a total of 4,300 persons, are situated below sources of pollution; however, no serious contamination problem exists in connection with these supplies. Thirteen of the surface supplies are coagulated, settled, and filtered, and all but 1 of these 13 are chlorinated. The 2 remaining surface supplies receive no treatment. Industrial water supply presents no major problem.

423. Discharge data for the Salt River are meager, the longest record being of but 18 months' duration. However, the recreational appeal of the streams of the basin is lessened because of the low flows which usually prevail during summer months.

424. *Sources of pollution.*—About 20,300 persons, or 15 percent of the total population of the basin, are served by sewers. Industrial wastes after application of various corrective measures, contribute an additional net population equivalent of 98,900 (based on biochemical oxygen demand), almost all of which is from distilleries. Less than 1 percent of the industrial waste load receives further treatment in municipal plants. At all 27 industrial establishments which are sources of wastes not receiving municipal treatment, at least minor corrective measures have been taken. One primary and seven secondary municipal waste-treatment plants, in which about $670,000 have been invested, serve 1,700 and 15,400 persons, respectively, and aid in reducing the combined population equivalent of domestic and industrial wastes to about 105,300, as discharged. Summarized data follow:

Waste sources:			
Total population (1940 census)			139, 868
Sewered population:			
Connected to municipal treatment		17, 100	
Not connected to municipal treatment		3, 200	
			20, 300
Industrial wastes (population equivalent after application of independent corrective measures now in force but prior to other treatment):			
Connected to municipal treatment		700	
Not connected to municipal treatment:			
Distillery	97, 500		
Milk	700		
		98, 200	
			98, 900
Total (population equivalent)			119, 200
Wastes as discharged:			
Human wastes (sewered) (population equivalent after all present treatment):			
Connected to municipal treatment		3, 600	
Not connected to municipal treatment		3, 200	
			6, 800
Industrial wastes (population equivalent after all present treatment):			
Connected to municipal treatment		300	
Not connected to municipal treatment		98, 200	
			98, 500
Total waste residual (population equivalent)			105, 300

NOTE.—Single industries of a specific classification are included within the miscellaneous classification.

425. *Extent of pollution.*—The Public Health Service collected and analyzed more than 90 water samples from over 20 stream stations during July, August, and October 1940 and February 1941. Areas which showed evidence of pollution in the analytical results are as follows:

(*a*) Town Branch below Harrodsburg: Three samples in August 1940, showed complete oxygen depletion, an average biochemical oxygen demand of 19.9 parts per million, and 45,000 coliform bacteria per milliliter. Discharge averaged 1 cubic foot per second.

(*b*) Salt River above Lawrenceburg: Three samples in August 1940, showed an average dissolved oxygen content of 4.3 parts per million with a flow of 2 cubic feet per second.

(*c*) Hammonds Creek below Lawrenceburg: Three samples in August 1940, showed a 2.6 parts per million dissolved oxygen average and an average coliform bacteria count of 365 per milliliter.

(*d*) Clear Creek below Shelbyville: Three samples at a single station showed an average dissolved oxygen content of 3.7 parts per million in August 1940. Biochemical oxygen demand averaged 10.4 parts per million.

(*e*) Road Run below Springfield: Three samples in August 1940 showed complete oxygen depletion.

(*f*) Hardings Creek below Lebanon: An average dissolved oxygen content of 2.6 parts per million was observed in three samples collected during August 1940. Biochemical oxygen demand averaged 13.0 parts per million, coliform bacteria content 10,900 per milliliter.

(*g*) Salt River 6 miles above mouth: Two samples in October 1940 had an average dissolved oxygen content of 4.0 parts per million.

426. In August 1940, while flows were low, partial oxygen depletion was also noted in Mill Creek below Fort Knox and at the mouth of the Salt River. With the exception of localized areas below pollution sources, dissolved oxygen values were, in general, above 6.5 parts per million, and biochemical oxygen demand was low; pH values were observed to be uniformly above 7.0.

427. Average analytical results for 13 sampling dates during the period August 1940 to February 1941 indicated the Salt River at its mouth to be similar in quality to the Ohio River above their junction. Although average coliform bacteria counts were about equal at the stations, results for the main stream were higher than those for the tributary on ten of the sampling days.

428. Plates 38, 39, and 40 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results for the Salt River Basin.

429. *Methods of pollution control.*—Distillery wastes present the most serious remaining pollution problem in the Salt River Basin. Although all distilleries have taken some corrective measures, further steps appear to be justified. Other pollution problems present no technical difficulties.

430. The cost of a suggested pollution-control program is shown in the following table. The program will eliminate local nuisance conditions and improve surface waters for recreational and water-supply purposes.

Suggested program of pollution control for the Salt River Basin—Economic aspects

Suggested pollution-control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Secondary	7	3,200	6,000	7,200	$140,000	$7,000	$10,000	$17,000
Improvements	1	1,700	4,700		60,000	3,000	4,000	7,000
Subtotal	8	4,900	10,700		200,000	10,000	14,000	24,000
Interceptors					10,000	(1)	1,000	1,000
Industrial treatment	(2)				250,000	4,000	41,000	45,000
Subtotal					460,000	14,000	56,000	70,000
Emergency allowance, 20 percent [3]					90,000			
Total					550,000			

[1] Negligible.
[2] Includes such items as minor corrections, process changes, sewer construction, treatment plants, etc.
[3] Estimated additional cost of program if provided during present emergency period.

Appendix P

GREEN RIVER BASIN

SUMMARY

431. *General description.*—The Green River Basin comprises 9,220 square miles, situated almost entirely within west central Kentucky. A 380-square-mile portion of the tributary Barren River Basin is situated in Tennessee. Other important tributaries include the Pond, Mud, Nolin, and Rough Rivers and Russell Creek. The main stream joins the Ohio River 784.2 river-miles below Pittsburgh, Pa. The basin's surface is uneven, with occasional hills from 300 to 400 feet high and river channels cut from 100 to 200 feet below the uplands. A general map of the basin is shown on plate 41.

432. Agriculture is the principal occupation in the Green River Basin, although much of the area is too hilly for cultivation. Coal is mined in the western portion of the valley. Natural resources, in addition to coal, include water power, oil, gas, rock asphalt, timber, and commercial stones. The river is navigable for almost 200 miles above its mouth.

433. The urban populaton of the valley has almost doubled since 1910 and now approximates 44,400. Rural population has not varied appreciably during the same period. The present total population of the basin is about 444,400 of which about 90 percent is rural. Bowling Green, Ky., with a population of 14,585, is the only community of over 10,000 persons.

434. *Water uses.*—There are 39 public water supplies in the basin of which 21, aggregating about 3.17 million gallons per day and serving about 50,300 persons, or over 70 percent of the population which uses public supplies, are from surface sources. Nine of the latter are located below community sewer outfalls; however, none of these supplies is seriously polluted. Chlorination is practiced

on all surface supplies except at Brownsville, Ky., where a 0.02 million gallons per day supply receives no treatment. Eighteen of the surface supplies are settled, and of these 17 are coagulated and 16 filtered.

435. The Green River and most of its tributaries are considered good fishing streams and are extensively used for recreation by local residents. Water supply for industrial purposes presents no major problem.

436. Low-flow characteristics at two selected stream stations in the basin are as follows:

Stream	Green River	Rough River
Location	Livermore, Ky.	Dundee, Ky.
Period considered	1930-40	1930-40
Drainage area (square miles)	7,580	764
June to September discharge (cubic feet per second):		
Minimum single month	482	27
Minimum 4-month average	718	40
Average	3,930	296

437. *Sources of pollution.*—About 45,000 persons, or 10 percent of the population of the basin, are served by sewers. Industrial wastes, after application of various corrective measures, contribute an additional net population equivalent of 3,800 (based on biochemical oxygen demand) of which 37 percent receives further treatment in municipal plants. Of the 6 establishments whose wastes do not receive municipal treatment, 5 have taken at least minor steps toward pollution control. Eight primary and 3 secondary municipal waste treatment plants, in which about $450,000 have been invested, serve 29,300 and 5,000 persons, respectively, and aid in reducing the combined population equivalent of domestic and industrial wastes to about 33,800, as discharged. Summarized data follow:

Waste sources:			
Total population (1940 census)			444, 392
Sewered population:			
Connected to municipal treatment		34, 300	
Not connected to municipal treatment		10, 700	
			45, 000
Industrial wastes (population equivalent after application of independent corrective measures now in force but prior to other treatment):			
Connected to municipal treatment		1, 400	
Not connected to municipal treatment:			
Meat	1, 800		
Milk	400		
Miscellaneous	200		
		2, 400	
			3, 800
Total (population equivalent)			48, 800
Wastes as discharged:			
Human wastes (sewered) (population equivalent after all present treatment):			
Connected to municipal treatment		20, 100	
Not connected to municipal treatment		10, 700	
			30, 800

Wastes as discharged—Continued

Industrial wastes (population equivalent after all present treatment):		
Connected to municipal treatment	600	
Not connected to municipal treatment	2, 400	
		3, 000
Total waste residual (population equivalent)		33, 800

NOTE.—Single industries of a specific classification are included within the miscellaneous classification.

438. Mine sealing has reduced the acid load carried by the streams at the inception of the sealing program by about 20 percent. The present acid load is about 61,385 tons of acid per year (calcium carbonate equivalent).

439. *Extent of pollution.*—The Public Health Service collected and analyzed more than 140 water samples from over 45 stream stations in the basin during August to November 1940, and in February 1941. More than 90 percent of the samples were collected in August and October 1940. With the exception of 1 sampling date in February 1941, flows were uniformly less than the mean summer discharge of record, and approached the minimum flow of record on tributary streams. On small tributaries, sewage comprised from 65 to 75 percent of the total flow below sewer outfalls.

440. Monthly average dissolved oxygen results of less than five parts per million were observed in Valley Creek in and below Elizabethtown, Ky.; in the South Fork of Beaver Creek below Glasgow, Ky.; in Town Branch below Franklin, Ky.; in Mud River below Russellville, Ky.; in Muddy Creek below Beaver Dam, Ky.; in Flat Creek below Madisonville, Ky.; in Cypress Creek below Central City, Ky.; in the North Fork of Nolin River above Hodgensville, Ky., and in the Rough River above lock and dam No. 1. Monthly averages are each based on analytical results for three samples.

441. Monthly average biochemical oxygen demand results of five parts per million or more, based on three samples each, were observed in Buckhorn Creek below Campbellsville, Ky.; in Valley Creek in and below Elizabethtown, Ky.; in the South Fork of Beaver Creek below Glasgow, Ky.; in Bays Fork below Scottsville, Ky.; in Town Branch below Franklin, Ky.; in Mud River below Russellville, Ky.; in Muddy Creek below Beaver Dam, Ky.; in Flat Creek below Madisonville, Ky.; and in Cypress Creek below Central City, Ky.

442. Coliform bacteria counts were in general agreement with dissolved oxygen and oxygen demand results as to the location of major sources of pollution, these being Campbellsville, Ky.; Elizabethtown, Ky.; Glasgow, Ky.; Scottsville, Ky.; Franklin, Ky.; Russellville, Ky.; Beaver Dam, Ky.; Madisonville, Ky.; and Central City, Ky.

443. Acid stream conditions, resulting from pollution by acid mine drainage, were observed on Drakes Creek in the tributary Pond River Basin. An average pH value of 3.3 was observed in three samples. At the time of the survey most mines were shut down, and those working were pumping mine water intermittently. During periods of higher stream flow and normal mine operations, acid conditions may be more general in the streams of the coal area drained by the Pond River.

444. Laboratory results for seven sampling dates in the period August 1940 to February 1941 showed the dissolved oxygen content of the Green River at the mouth to be lower than that of the Ohio River above their junction. The biochemical oxygen demand of the tributary was lower than that of the Ohio River in five cases, and equal to it in two, while the coliform bacteria content of the tributary was less than that of the main stream on all seven sampling days.

445. Plates 41, 42, and 43 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results for the Green River Basin.

446. *Methods of pollution control.*—Laboratory data showed no consequential effects of pollution in the Green River proper, the major problems being local nuisance below towns on the smaller streams. Secondary waste treatment appears justified at Central City, Ky.; Franklin, Ky.; and at five smaller domestic pollution sources. Supplemental treatment is indicated at seven communities which now have treatment plants. At Bowling Green, Ky., and Hartford, Ky., and at communities along the Green River, primary treatment should be sufficient to maintain satisfactory stream conditions. Primary treatment with continuous chlorination is indicated at Cave City, Ky., where all wastes enter the caverns beneath the town. Significant industrial pollutants can be treated at municipal plants and continuation of the mine sealing program would reduce the acidity of streams in the western part of the basin.

447. The cost of a suggested program of pollution control is shown in the following table. The program would eliminate local nuisance condition, preserve and improve the extensive recreational facilities of the basin, and improve surface waters for use as public water supplies.

Suggested program of pollution control for the Green River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primary	9	3,200	7,900	11,200	$150,000	$7,000	$10,000	$17,000
Secondary	7	7,700	15,400	17,200	290,000	15,000	20,000	35,000
Improvements	7	18,700	25,000		160,000	8,000	10,000	18,000
Subtotal	23	29,600	48,300		600,000	30,000	40,000	70,000
Interceptors					180,000	(1)	10,000	10,000
Mine sealing	(2)				310,000	33,000	13,000	46,000
Subtotal					1,090,000	63,000	63,000	126,000
Emergency allowance, 20 percent [3]					220,000			
Total					1,310,000			

[1] Negligible.
[2] Initial program contemplates sealing of 23,140 ton-years of acid.
[3] Estimated additional cost of program if provided during present emergency period.

APPENDIX Q

WABASH RIVER BASIN

SUMMARY

448. *General description.*—About 73 percent of the Wabash River Basin lies within Indiana, 26 percent within Illinois, and the remainder within Ohio. Its drainage area is 33,100 square miles, and the stream joins the Ohio River 848.0 river miles below Pittsburgh, Pa. Principal tributaries includes the Little Wabash (Indiana), Upper Eel, Tippecanoe, Vermilion, Embarrass, Little Wabash (Illinois), White, Patoka, and Mississinewa Rivers, and Wild Cat and Sugar Creeks. Much of the Wabash River Basin is of the glacial plains region of the upper Mississippi Basin. Elevations range from about 300 to about 1,300 feet above mean sea level. A general map of the basin is shown on plate 44.

449. Agriculture is the most important single occupation in the Wabash River Basin. Much of the agricultural products are processed locally. Industrial development is diversified. Coal, oil, and limestone are among the mineral resources of the basin. The river is not commercially navigable.

450. The present population of the watershed is about 2,508,600 of which about 48 percent is urban. Indianapolis, Ind., has about 386,970 inhabitants and is the largest city. Thirteen other communities have populations ranging between 15,000 and 65,000.

451. *Water uses.*—In the basin there are 275 public water supplies of which 46, aggregating about 77.39 million gallons per day and serving about 752,600 persons, are from surface sources. Thirty of the surface supplies, serving about 687,500 persons, are below community sewer outfalls. Coagulation, sedimentation, filtration, and chlorination are applied to all but one of the supplies subject to pollution. Ground water is not sufficiently plentiful for use by the larger cities and, in addition, is generally hard and contains objectionable amounts of iron.

452. Natural and artificial lakes in the basin are extensively used for recreation, and local residents use many streams for fishing and swimming. Industrial water supply is not a major problem.

453. Low flow characteristics at 2 stream stations in the basin are as follows:

Stream	Wabash River	White River
Location	Mount Carmel, Ill.	Hazelton, Ind.
Drainage area (square miles)	28,600	11,300
Period considered	1928–40	1924–38
June to September discharge (cubic feet per second):		
Minimum single month	2,330	870
Minimum 4-month average	3,780	1,292
Average	12,192	5,889

454. *Sources of pollution.*—About 1,119,700 persons, or 45 percent of the population of the basin, are served by sewers. Industrial wastes contribute an additional population equivalent of 1,772,000 (based on biochemical oxygen demand) after application of various corrective measures, of which 547,500, or 31 percent, receives municipal treatment. Of the 250 establishments whose wastes do not

receive municipal treatment, about half are canneries, which, together with 12 paper plants, account for about 80 percent of the industrial waste load in this category. At least minor waste corrective measures have been taken at 217 plants. Ten primary and 74 secondary municipal waste treatment plants, in which about $16,650,000 have been invested, serve 39,100 and 782,900 persons, respectively, and help to reduce the combined population equivalent of domestic and industrial wastes as discharged to streams to about 1,818,900. Summarized data follow:

Waste sources:			
Total population (1940 census)			2, 508, 598
Sewered population:			
Connected to municipal treatment		822, 000	
Not connected to municipal treatment		297, 700	
			1, 119, 700
Industrial wastes (population equivalent after application of independent corrective measures now in force but prior to other treatment):			
Connected to municipal treatment		547, 500	
Not connected to municipal treatment:			
Brewing	42, 000		
Canning	530, 000		
Distilling	121, 000		
Meat	36, 100		
Milk	11, 900		
Oil refining	17, 000		
Paper	444, 300		
Textile	8, 200		
Miscellaneous	14, 000		
		1, 224, 500	
			1, 772, 000
Total (population equivalent)			2, 891, 700
Wastes as discharged:			
Human wastes (sewered) (population equivalent after all present treatment):			
Connected to municipal treatment		164, 100	
Not connected to municipal treatment		297, 700	
			461, 800
Industrial wastes (population equivalent after all present treatment):			
Connected to municipal treatment		132, 600	
Not connected to municipal treatment		1, 224, 500	
			1, 357, 100
Total waste residual (population equivalent)			1, 818, 900

NOTE.—Single industries of a specific classification are included within the miscellaneous classification.

455. In general, wastes from oil fields are not at present a major pollution problem. Production in older fields having relatively high brine-oil ratios is small, and brine production in new fields drained by the Little Wabash River is at present not large. New activity in old fields in Indiana has seriously affected the Patoka River; and Princeton, Ind., is being forced to abandon its water supply from that stream. Steps are being taken to prevent the development of a serious problem in the new fields.

456. Pollution from acid mine drainage has caused the greatest damage in the area drained by the Patoka River. Mine sealing has reduced the original acid load by about 43 percent, and the present load in the basin amounts to about 62,790 tons of acid per year (calcium carbonate equivalent).

457. *Extent of pollution.*—The Public Health Service collected and analyzed over 1,000 water samples from more than 275 stream stations in the basin during the period from July to November 1940. Two samples were collected in February 1941. Discharge conditions during the sampling period were among the lowest of record. Reaches showing the greatest extent of pollution are the following:

(*a*) Wabash River below Terre Haute: Average results for 5 samples, collected from each of 5 stations in a 30-mile reach below Terre Haute, during September and October, 1940, showed dissolved oxygen from 2.6 to 4.6 parts per million, biochemical oxygen demand from 3.4 to 12.1 parts per million, and coliform bacteria counts from 349 to 34,000 per milliliter. Discharge on sampling dates approximated the minimum June-to-September average of record. Four samples collected at each of the same stations during November 1940 under similar discharge conditions, but with temperatures averaging about 10° C. lower, showed much less severe oxygen depletion, average results ranging from 8.8 to 10.6 parts per million.

(*b*) West Fork of White River below Indianapolis: Average results for 5 samples, collected at each of 3 stations during September 1940 in an 18-mile reach below Indianapolis, showed dissolved oxygen ranging from 2.9 to 3.9 parts per million, biochemical oxygen demand of from 4.4 to 9.1 parts per million, and coliform bacteria counts from 34 to 23,200 per milliliter. Corresponding samples, from a station 20 miles below the downstream traverse point, showed an average of 9.9 parts per million of dissolved oxygen. Discharge was extremely low on sampling dates.

458. Many small streams are grossly polluted, and poor sanitary conditions were observed on the upper Wabash River from Fort Recovery, Ohio, to below Bluffton, Ind. More or less localized pollution problems were observed at Hartford City, Ind.; Portland, Ind.; Gas City, Ind.; Columbia City, Ind.; Warsaw, Ind.; Kokomo, Ind.; Frankfort, Ind.; Rantoul, Ill.; West Baden, Ind.; Danville, Ill.; Mattoon, Ill.; Flora, Ill.; Albion, Ill.; Muncie, Ind.; Elwood, Ind.; and Franklin, Ind.

459. Laboratory results for 8 sampling dates during the period September 1940 to February 1941 showed the dissolved oxygen content of the Wabash River at the mouth to be higher than that of the Ohio River above their junction on about half of the sampling days. The biochemical oxygen demand and coliform bacteria content of the tributary were respectively higher and lower than those of the Ohio River on a majority of the sampling days.

460. Plates 44, 45, and 46 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results for the Wabash River Basin.

461. *Methods of pollution control.*—In spite of substantial progress toward the abatement of industrial pollution, industrial wastes at present cause the most serious pollution problems in the Wabash River Basin. However, a large part of the industrial waste load can be most easily and satisfactorily handled in municipal treatment plants. The cost of a suggested pollution control problem is shown in the following table. The probable accomplishments of such a program would be varied because of the extent and wide application of the streams of the Wabash River Basin. In general, the program would eliminate local nuisance, improve streams for public-water supplies,

establish new, more satisfactory sources of public-water supply, and improve aquatic recreational facilities.

Suggested program of pollution control for the Wabash River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primary	30	142,800	212,900	314,000	$2,130,000	$100,000	$150,000	$250,000
Secondary	132	149,800	257,100	318,000	5,310,000	235,000	375,000	610,000
Improvements	24	495,200	544,500		1,430,000	40,000	100,000	140,000
Subtotal	186	787,800	1,014,500		8,870,000	375,000	625,000	1,000,000
Interceptors					3,960,000	(1)	185,000	185,000
Industrial treatment	(2)				1,690,000	250,000	220,000	470,000
Mine sealing	(3)				80,000	9,000	3,000	12,000
Subtotal					14,600,000	634,000	1,033,000	1,667,000
Emergency allowance, 20 percent [4]					2,920,000			
Total					17,520,000			

[1] Negligible.
[2] Includes such items as minor corrections, process changes, sewer construction, treatment plants, etc.
[3] Initial program contemplates sealing of 30,403 ton-years of acid.
[4] Estimated additional cost of program if provided during present emergency period.

Appendix R

CUMBERLAND RIVER BASIN

SUMMARY

462. *General description.*—The basin of the Cumberland River comprises 18,000 square miles located within Kentucky and Tennessee. Its topography varies from rugged mountains in the east to rolling low plateau areas in the west. Elevations range from about 300 to about 4,150 feet above mean sea level. The stream joins the Ohio River 920.4 river miles below Pittsburgh, Pa., and principal tributaries are Laurel, Rockcastle, Big South Fork, Obey, Caney Fork, Stone, Harpeth, Red, and Little Rivers. A general map of the basin is shown on plate 41.

463. Agriculture, mining, and manufacturing are principal economic pursuits. Manufactured products include cement, brick, lumber, rayon, textiles, chemicals, stoves, shoes, steel fabrications, furniture, mattresses, snuff, flour, feed, beverages, food preparations, leather, and airplanes. Coal is the most important mineral product, and deposits of fluorite, petroleum, limestone, shale, sandstone, sand, gravel, phosphate rock, and iron ore have been or are being worked in the basin. Waterpower possibilities are excellent. The main stream and downstream reaches of principal tributaries are commercially navigable. Construction of the Wolf Creek, Center Hill, and Dale Hollow reservoir dams to provide flood control and hydroelectric power has been initiated by the Corps of Engineers.

464. Nashville, Tenn., the population and industrial center of the basin, now has about 167,400 inhabitants; other large communities and their populations (1940 census) are as follows:

Clarksville, Tenn	11, 831	Hopkinsville, Ky	11, 724
Middlesboro, Ky	11, 777	Murfreesboro, Tenn	9, 495

The total population of the basin has increased about 31 percent since 1910, to approximately 1,129,000 of which about 25 percent is urban.

465. *Water uses.*—There are 92 public water supplies in the basin of which 30, aggregating about 27.68 million gallons per day and serving 290,800 persons, or about 80 percent of the population which uses public supplies, are from surface sources. Sixteen of the latter are located below community sewer outfalls. However, surface supplies are not seriously affected by pollution. Over 90 percent of the total volume of surface public water supply is coagulated, settled, filtered, and chlorinated. The remaining supplies, all small, receive lesser treatment. Softening is not practiced on surface waters. Ground water supplies are limited and of rather poor chemical quality, and, as a consequence, many of them have been abandoned in favor of surface sources.

466. Extensive use is made of the streams for recreational purposes, including fishing, bathing, and boating. Industrial water supply is not a major problem.

467. Low flow characteristics at three selected stream stations in the basin are as follows:

Stream	Cumberland River	Caney Fork	South Fork
Location	Clarksville, Tenn.	Silver Point, Tenn.	Nevelsville, Ky.
Drainage area (square miles)	15,780	2,130	1,275
Period considered	1922–40	1923–40	1915–39
June to September discharge (cubic feet per second):			
Minimum single month	1, 099	289	28
Minimum 4-month average	2, 650	439	55
Average	10, 183	1, 608	836

468. *Sources of pollution.*—About 80 percent of the total pollution load of the basin enters the Cumberland River in the 40-mile reach from Old Hickory, Tenn., to and below Nashville, Tenn. A total of 237,300 persons, or 21 percent of the population of the basin, is served by sewers. Industrial wastes, after application of various corrective measures now in force, contribute an additional population equivalent of 258,500 (based on biochemical oxygen demand) of which 7 percent receives further treatment in municipal plants. Of the 68 establishments whose wastes do not receive municipal treatment, 23 have taken at least minor corrective measures.

469. Seven primary and 10 secondary municipal waste treatment plants, in which about $1,660,000 have been invested, serve 9,300 and 55,000 persons, respectively, and aid in reducing the combined popula-

tion equivalent of domestic and industrial wastes to about 430,700, as discharged. Summarized data follow:

Waste sources:			
Total population (1940 census)			1,129,002
Sewered population:			
Connected to municipal treatment		64,300	
Not connected to municipal treatment		173,000	
			237,300
Industrial wastes (population equivalent after application of independent corrective measures now in force but prior to other treatment):			
Connected to municipal treatment		17,900	
Not connected to municipal treatment:			
Canning	2,100		
Chemical	72,000		
Meat	37,500		
Milk	9,600		
Oil refining	1,200		
Textile	9,000		
Miscellaneous	109,200		
		240,600	
			258,500
Total (population equivalent)			495,800
Wastes as discharged:			
Human wastes (sewered) (population equivalent after all present treatment):			
Connected to municipal treatment		14,100	
Not connected to municipal treatment		173,000	
			187,100
Industrial wastes (population equivalent after all present treatment):			
Connected to municipal treatment		3,000	
Not connected to municipal treatment		240,600	
			243,600
Total waste residual (population equivalent)			430,700

NOTE.—Single industries of a specific classification are included within the miscellaneous classification.

470. Mine sealing has reduced the original acid load carried by the streams of the basin by about 26 percent, to a present load of approximately 195,910 tons per year (calcium carbonate equivalent).

471. *Extent of pollution.*—During the period from August 1940 to March 1941 the Public Health Service collected and analyzed more than 310 water samples from over 95 stream stations in the basin. Data for the Nashville area were developed by the Tennessee State Health Department in 1938 and 1939. Seventy-nine percent of the sampling by the United States Public Health Service was done during the fall of 1940. Discharges on sampling days during this period were considerably lower than the mean summer flows of record, except in eastern Kentucky, where local rains increased discharges and hence influenced analytical results.

472. Minimum dissolved oxygen results at 5 stations in a 30-mile reach below Nashville, Tenn., varied from 0.1 to 4.1 parts per million during the summers of 1938 and 1939. Maximum biochemical oxygen demand varied from 1.5 to 6.0 parts per million, and maximum coliform bacteria counts ranged from 200 to 8,000 per milliliter.

473. Exclusive of the Nashville area, monthly dissolved oxygen results of 5 parts per million or less were observed below Jellico and Oneida, Tenn., and below Middlesboro, London, Corbin, Mount Vernon, Hopkinsville, and Princeton, Ky., all on smaller tributaries. Complete oxygen depletion, denoting septic conditions, was observed below London and Oneida. Three samples are represented in each average. Dissolved oxygen results show the main river to be in good sanitary condition except below Old Hickory and Nashville, Tenn.

474. Exclusive of the Nashville area, monthly average biochemical oxygen demand results of 5 parts per million or more, based on from two to four samples each, were observed below each of the towns listed in the preceding paragraph and also below Lynch, Somerset, and Guthrie, Ky., and Cooksville, Lebanon, Gallatin, Woodbury, Dickson, and Springfield, Tenn., all on smaller tributaries.

475. Average coliform bacteria counts were in general agreement with dissolved oxygen and oxygen demand results in indicating the major sources of pollution. The most unfavorable results were observed below Nashville, Oneida, and Dickson, Tenn., and Middlesboro, London, Corbin, Mount Vernon, and Princeton, Ky.

476. Coal-washing operations produce visual pollution in Fugitt Creek, Clover Fork, Clear Fork, and Hickory Creek, but acid stream conditions were not observed.

477. Laboratory results for eight sampling dates during the period September 1940 to March 1941 showed the dissolved oxygen content and the biochemical oxygen demand of the Cumberland River at the mouth to be lower than that of the Ohio River above their junction on all sampling days, while the coliform bacteria content of the tributary was equal to or less than that of the Ohio River on 75 percent of the sampling days.

478. Plates 41, 42, and 43 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results for the Cumberland River Basin.

479. *Methods of pollution control.*—The only pollution problem of serious consequence found in the Cumberland River Basin is in the Nashville area. Minor pollution of local significance occurs at a number of smaller communities on tributary streams. Wolf Creek, Dale Hollow, and Center Hill Reservoirs, now under construction, will furnish minimum summer flows in quantities such that primary treatment of sewage and equivalent treatment of industrial wastes at Old Hickory and Nashville, Tenn., will be adequate to maintain satisfactory stream conditions. Secondary treatment seems justified at Corbin and Lynch, Ky., and at 16 other small pollution sources on tributary streams in Kentucky and Tennessee, where near-zero summer flows occur. Supplemental treatment is suggested at Princeton, Monticello, and London, Ky. In addition to the Nashville area, primary treatment is indicated at five communities at the head of the basin in Kentucky, at Clarksville, Tenn., and at five smaller communities in Tennessee, in the middle reaches of the basin.

480. The cost of a suggested program of pollution control is shown in the following table. The program would eliminate local nuisance

conditions, improve streams for use as public water supplies, and preserve and enhance the value of extensive recreational facilities in the basin. Poor Fork, at the head of the basin, offers a favorable site for development of low flow control storage. Flow augmentation if provided at this site would be available at five downstream communities where the need for secondary sewage treatment is now indicated, and would assure satisfactory stream conditions at these localities after provision of primary treatment alone.

Suggested program of pollution control for the Cumberland River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primary	13	134,700	202,000	283,500	$1,280,000	$81,000	$90,000	$171,000
Secondary	18	37,300	58,000	62,100	970,000	50,000	70,000	120,000
Improvements	3	6,500	9,400		80,000	4,000	5,000	9,000
Subtotal	34	178,500	269,400		2,330,000	135,000	165,000	300,000
Interceptors					4,540,000	(1)	215,000	215,000
Industrial treatment	(2)				270,000	15,000	35,000	50,000
Mine sealing	(3)				780,000	84,000	33,000	117,000
Subtotal					7,920,000	234,000	448,000	682,000
Emergency allowance, 20 percent [4]					1,580,000			
Total					9,500,000			

[1] Negligible.
[2] Includes such items as minor corrections, process changes, sewer construction, treatment plants, etc.
[3] Initial program contemplates sealing of 93,070 ton-years of acid.
[4] Estimated additional cost of program if provided during present emergency period.

Appendix S

TENNESSEE RIVER BASIN

SUMMARY

481. *General description.*—The Holston and French Broad Rivers merge east of Knoxville, Tenn., to form the Tennessee River. This river system drains most of the State of Tennessee and small portions of Virginia, North Carolina, Georgia, Alabama, Mississippi, and Kentucky. The area of the basin is about 40,600 square miles and the stream joins the Ohio River 934.5 river miles below Pittsburgh, Pa. The upstream area, above Chattanooga, Tenn., is rugged and mountainous in character and, with the exception of the main valley, generally wooded. In the lower valley, streams meander through broad flood plains and agricultural lands predominate. The basin is rich in natural resources, the more important of which are coal; asphalt; clay; sand; gravel; limestone; phosphate rock; ores of iron, zinc, and copper; and abundant water power. A general map of the basin is shown on plate 47.

482. The basin is primarily rural in character and agriculture is generally practiced; however, practically every type of industry is

represented. Projects of the Tennessee Valley Authority provide flood control, hydroelectric power, navigation, and recreational facilities of importance. The total population of the basin has increased about 39 percent since 1910 and now approximates 2,491,300 of which about 25 percent is urban. Urban population has increased much more rapidly than has rural population during the period. The larger cities and their populations (1940 census), are as follows:

Chattanooga, Tenn	128, 163	Asheville, N. C	51, 310
Knoxville, Tenn	111, 580	Johnson City, Tenn	25, 332

Twenty-three other communities in the Tennessee River Valley have more than 5,000 inhabitants.

483. *Water uses.*—There are 244 public water supplies in the basin of which 76, serving about 608,500 persons and aggregating about 59.97 million gallons per day, are from surface sources; the latter include all major supplies. One hundred and eighty-eight supplies are chlorinated, including both surface and other supplies, and 68 of these receive additional treatment. Faulted geological formations which permit polluted surface waters to pass more or less directly to underground sources account for the high percentage of chlorination practiced. Eighty-two percent of the surface water used for public supplies is coagulated, settled, filtered, and chlorinated. There are 23 communities whose water supply intakes are located below community sewer outfalls. In general, however, water supplies are not seriously affected by pollution except at Knoxville, Tenn.

484. Industrial water usage is not now a major problem; however, it is anticipated that continuing development of the basin by the Tennessee Valley Authority will be accompanied by an increase in industrial development, which probably will result in an increase in industrial water demand.

485. Low flow characteristics at three selected stream stations in the basin follow:

Stream	Tennessee River	Little Tennessee River	South Fork, Holston River
Location	Florence, Ala.	McGhee, Tenn.	Kingsport, Tenn.
Drainage area (square miles)	30, 810	2, 443	1, 931
Period considered	1894–1939	1905–40	1925–40
June to September discharge (cubic feet per second):			
Minimum single month	3, 760	609	630
Minimum 4-month average	7, 675	1, 500	840
Average	30, 149	4, 226	1, 7[illegible]

486. *Sources of pollution.*—About 591,300 persons, or 24 percent of the population of the basin, are served by sewers. Industrial wastes, after application of various corrective measures now in force, contribute an additional net population equivalent of 1,306,000 (based on biochemical oxygen demand) of which 5,400, or less than 1 percent, receives further treatment in municipal plants. The pulp, paper, and cellulose industries discharge over half of the organic pollution load. Of the 227 industrial establishments whose wastes do not receive municipal treatment, 41 have taken at least minor corrective measures toward pollution control. Twenty-six primary and 18 secondary municipal waste-treatment plants, in which about $2,750,000 have been invested, serve 41,800 and 56,600 persons, respectively, and aid in

reducing the net population equivalent of domestic and industrial wastes to about 1,832,600, as discharged. Summarized data follow:

Waste sources:			
Total population (1940 census)			2, 491, 298
Sewered population:			
Connected to municipal treatment		98, 400	
Not connected to municipal treatment		492, 900	
			591, 300
Industrial wastes (population equivalent after application of independent corrective measures now in force but prior to other treatment):			
Connected to municipal treatment		5, 400	
Not connected to municipal treatment:			
Canning	38, 400		
Chemical	353, 200		
Meat	40, 200		
Milk	9, 500		
Pulp and paper	584, 400		
Tanning	79, 900		
Textile	138, 700		
Miscellaneous	56, 300		
		1, 300, 600	
			1, 306, 000
Total (population equivalent)			1, 897, 300
Wastes as discharged:			
Human wastes (sewered) (population equivalent after all treatment):			
Connected to municipal treatment		36, 700	
Not connected to municipal treatment		492, 900	
			529, 600
Industrial wastes (population equivalent after all treatment):			
Connected to municipal treatment		2, 400	
Not connected to municipal treatment		1, 300, 600	
			1, 303, 000
Total waste residual (population equivalent)			1, 832, 600

NOTE.—Single industries of a specific classification are included within the miscellaneous classification.

487. Pollution from acid mine drainage amounts to about 21,970 tons per year (calcium carbonate equivalent). Mine sealing has reduced the original acid load by about 42 percent.

488. *Extent of pollution.*—During the period from September 1940 to March 1941 the Public Health Service collected and analyzed more than 290 water samples from over 100 stream stations in the basin. Ninety-seven percent of the samples were collected in January, February, and March, 1941. Use was made of data collected by the Tennessee Valley Authority on the Tennessee River and its tributaries during the period from 1936 to 1939. Discharges on Public Health Service sampling days, during the summer and fall months of 1940, corresponded approximately with the mean summer flows of record on tributary streams, while those of the main stream for the February 1941 sampling period were considerably lower than mean summer flows. Among stream reaches showing extreme pollution, as indicated by United States Public Health Service and Tennessee Valley Authority laboratory results, are the following:

(*a*) Pigeon River below Canton, N. C.: This stream is the principal waste carrying tributary of the basin, receiving a pollution load of 309,000 net population equivalent, of which 298,000 or 96 percent,

is from industrial establishments. Three samples at each of 2 stations in a 6 mile reach below Canton, N. C., showed average dissolved oxygen contents of 0.9 and zero parts per million, respectively, and coliform bacteria counts of 1,040 and 1,260 per milliliter. Average biochemical oxygen demands were 238 and 208 parts per million. Samples were collected in February and March 1941. Average discharge was 128 cubic feet per second, which is lower than mean summer flow in this reach.

(*b*) Holston River below Kingsport, Tenn.: Samples collected by the Tennessee Valley Authority at one station on the South Fork of the Holston River, during the period from May to October, 1941, showed average dissolved oxygen results of 6.1 parts per million, an average coliform bacteria count of 475 per milliliter, and an average biochemical oxygen demand of 5.9 parts per million. Average discharge was 2,510 cubic feet per second, slightly higher than mean summer flow.

(*c*) Tennessee River below Knoxville, Tenn.: Records show dissolved oxygen results falling to 4.0 parts per million, and coliform bacteria counts averaging 650 per milliliter during summer months. Water supply for the city of Knoxville, Tenn., has frequently been endangered and at times damaged by industrial wastes from plants on the Holston and French Broad Rivers.

(*d*) Tennessee River below Chattanooga, Tenn.: Laboratory findings show dissolved oxygen results falling to 5.5 parts per million at moderate flow, with the probability of lower values at times of low flow. Below the city, coliform bacteria counts were found to be in excess of 200 per milliliter during half of the months of the sampling period. Three samples taken in February 1941 from Chattanooga Creek, which receives wastes at Rossville, Ga., and from the southern part of Chattanooga, showed an average dissolved oxygen content of 1.1 parts per million, an average coliform bacteria count of 2,410 per milliliter, and an average biochemical oxygen demand of 92.8 parts per million.

489. In general, pollution problems resulting from sewage are primarily local. Only at Chattanooga, Tenn., and Knoxville, Tenn., and in the vicinity of Asheville, N. C., does human sewage contribute materially to pollution problems of other than local extent.

490. Acid stream conditions caused by copper and iron mining, and manufacturing activities, were observed in the vicinity of Copperhill, Tenn., on the Ocoee River. Three samples taken at each of 3 stations in February 1941 showed average pH values of 4.1, 4.9, and 5.1, respectively.

491. Laboratory results for 8 sampling days during the period September 1940 to March 1941 showed the dissolved oxygen content and biochemical oxygen demand of the Tennessee River at the mouth to be consistently less than that of the Ohio River above their junction. Coliform bacteria counts were low at both stations on all sampling dates.

492. Plates 47, 48, and 49 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results for the Tennessee River Basin.

493. *Methods of pollution control.*—Pollution problems of more than local consequence in the Tennessee River Basin are primarily the result of industrial wastes. Primary treatment of sewage and equivalent treatment of industrial wastes should be sufficient to restore desirable

stream conditions on the main river. Secondary and supplemental sewage treatment is indicated at numerous waste sources on smaller tributaries. Industrial waste treatment is needed to remedy gross pollution of the French Broad and Pigeon Rivers, and to eliminate major pollution problems on the Holston, Little Tennessee, Clinch, and Hiwassee Rivers.

494. The cost of a suggested program of pollution control is shown in the following table. The program would eliminate local nuisance conditions, improve streams for use as public water supplies, and restore and improve headwater tributary streams for recreational purposes.

Suggested program of pollution control for the Tennessee River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primary	64	373,400	491,000	670,000	$4,650,000	$245,000	$325,000	$570,000
Secondary	37	116,000	161,500	183,700	2,580,000	140,000	180,000	320,000
Improvements	9	20,700	29,000		190,000	10,000	15,000	25,000
Subtotal	110	510,100	681,500		7,420,000	395,000	520,000	915,000
Interceptors					15,450,000	(1)	725,000	725,000
Industrial treatment	(2)				1,610,000	190,000	205,000	395,000
Mine sealing	(3)				100,000	11,000	4,000	15,000
Subtotal					24,580,000	596,000	1,454,000	2,050,000
Emergency allowance, 20 percent [4]					4,920,000			
Total					29,500,000			

[1] Negligible.
[2] Includes such items as minor corrections, process changes, sewer construction, treatment plants, etc.
[3] Initial program contemplates sealing of 10,770 ton-years of acid.
[4] Estimated additional cost of program if provided during present emergency period.

Appendix T

OHIO RIVER BASIN

(Direct drainage)

SUMMARY

495. *General description.*—The Ohio River drains approximately 203,900 square miles, or about one-fifteenth of the area of the United States. The stream, formed by the junction of the Allegheny and Monongahela Rivers at Pittsburgh, Pa., flows 981 river miles to its confluence with the Mississippi River at Cairo, Ill., passing through a portion of western Pennsylvania and forming the southern boundaries of Ohio, Indiana, and Illinois and the northern boundaries of West Virginia and Kentucky. Plates 3, 6, and 9 include maps of the area comprising minor tributaries and direct Ohio River drainage.

496. The topography of the basin varies from wide valleys with gently sloping sides to narrow steep gorges where the river has cut through pre-glacial divides. Elevations range from about 250 to about 690 feet above mean sea level. Principal tributaries of the Ohio River in their order downstream from Pittsburgh, Pa., are the Allegheny, Monongahela, Beaver (right bank), Muskingum (right bank), Little Kanawha (left bank), Hocking (right bank), Kanawha (left bank), Guyandot (left bank), Big Sandy (left bank), Scioto (right bank), Little Miami (right bank), Licking (left bank), Miami (right bank), Kentucky (left bank), Salt (left bank), Green (left bank), Wabash (right bank), Cumberland (left bank), and Tennessee (left bank) Rivers. These and smaller minor tributaries are discussed separately.

497. Numerous industrial centers situated on the banks of the Ohio River include steel plants in the vicinity of Pittsburgh, Pa., and Wheeling, W. Va., large paper and meat-packing plants at Cincinnati, Ohio, and the tobacco industry at Louisville, Ky. Extensive sand and gravel deposits are found along the stream. The river is canalized for its entire length and navigation facilities are extensively used.

498. The urban population of the basin increased considerably between 1910 and 1930, but only slightly in the past decade. Most of the cities on the Ohio River are relatively old and their rate of growth during this century has been less rapid than that of other cities in the basin. The present population situated in communities on the main Ohio River is about 2,717,187, of which 95 percent is urban. Principal communities and their populations (1940 census) are as follows:

Pittsburgh, Pa	671, 659	Huntington, W. Va	78, 836
Cincinnati, Ohio	455, 610	Covington, Ky	62, 018
Louisville, Ky	319, 077	Wheeling, W. Va	61, 099
Evansville, Ind	97, 062		

499. *Water uses.*—A total of 121 domestic water supplies serve communities situated on the main Ohio River. Of these, 33 supplies, aggregating 172.11 million gallons per day and serving about 1,673,200 persons, are from surface sources. Thirty surface supplies, aggregating 170.88 million gallons per day and serving 1,663,000 persons are from the Ohio River and are subject to pollution from upstream sources. Over 1,000,000 persons are served by the 3 largest supplies at Cincinnati, Ohio; Louisville, Ky.; and Evansville, Ind. Three surface supplies aggregating 1.23 million gallons per day and serving 10,200 persons have been developed from unpolluted sources by Ohio River communities. The heavy pollution at many water intakes necessitates careful and complete treatment of the water. All supplies taken from the Ohio River are coagulated, settled, filtered, and chlorinated. Two are softened by the lime-soda process.

500. The river is used for recreation, in spite of excessive pollution. Boating, bathing, and sport fishing are carried on, and there is some commercial fishing in the lower reaches. One hydroelectric power project has been constructed by private interests at the falls of the Ohio at Louisville, Ky. Numerous reservoir sites on tributary streams have been studied with a view toward controlling floods in the Ohio River Valley. Industrial water supply is of considerable importance.

501. Low flow characteristics at three stations on the Ohio River are as follows:

Locations	Pittsburgh, Pa.	Cincinnati, Ohio	Louisville, Ky.
Drainage area (square miles)	19,000	76,570	91,200
Period considered	1923–40	1920–40	1928–40
June to September discharge (cubic feet per second):			
Minimum single month	1,300	4,300	4,900
Minimum 4-month average	3,900	7,700	11,000
Average	14,200	48,200	54,000

502. *Sources of pollution.*—About 2,092,200 persons, or 78 percent of the population of the basin, are served by sewers. In addition, sewage from about 640,000 persons in the Pittsburgh area enters the lower Allegheny and Monongahela Rivers just above their confluence at the head of the Ohio River, and sewage from about 78,000 persons in the Cincinnati area enters the Little Miami River near its mouth. Industrial wastes, after application of various corrective measures now employed, contribute a net population equivalent, based on biochemical oxygen demand, of about 2,400,000 to the Ohio River, about 415,000 to the Allegheny and Monongahela Rivers near their junction at Pittsburgh, and about 50,000 to the Little Miami River near its mouth at Cincinnati. None of these wastes receive further treatment in municipal plants. More than 80 percent of the organic industrial waste load is discharged from the Cincinnati area and downstream, the largest concentrations being at Cincinnati and Louisville.

503. Four primary and 16 secondary municipal waste treatment plants, in which about $1,080,000 have been invested, serve 6,100 and 16,400 persons respectively, and reduce the population equivalent of organic wastes to about 4,468,400, as discharged. Summarized data follow:

Waste sources:			
Total population (1940 census)			2,717,187
Sewered population:			
Connected to municipal treatment		22,500	
Not connected to municipal treatment		2,069,700	
			2,092,200
Industrial wastes (population equivalent after application of independent corrective measures now in force but prior to other treatment):			
Connected to municipal treatment		0	
Not connected to municipal treatment:			
Brewing	103,200		
Byproduct coke	234,000		
Canning	42,500		
Chemical	67,300		
Distilling	588,700		
Meat	118,200		
Milk	16,900		
Oil refining	46,100		
Paper	19,900		
Tanning	21,600		
Textile	44,400		
Miscellaneous	31,800		
Industrial wastes to Cincinnati sewers	1,057,400		
		2,392,000	
			2,392,000
Total (population equivalent)			4,484,200

Wastes as discharged:		
Human wastes (sewered) (population equivalent after all present treatment):		
Connected to municipal treatment	6, 700	
Not connected to municipal treatment	2, 069, 700	
		2, 076, 400
Industrial wastes (population equivalent after all present treatment):		
Connected to municipal treatment	0	
Not connected to municipal treatment	2, 392, 000	
		2, 392, 000
Total waste residual (population equivalent)		4, 468, 400

NOTE.—Single industries of a specific classification are included within the miscellaneous classification.

504. *Extent of pollution.*—During the period from February 1939 to March 1941 the Public Health Service collected and analyzed more than 3,420 water samples from over 90 stream stations on the Ohio River. In general, sampling in the middle reaches of the stream from Point Pleasant, W. Va., 265 river miles below Pittsburgh, Pa., to lock and dam No. 39 above Carrollton, Ky., 503 river miles below Pittsburgh, Pa., was carried on from February 1939 to April 1940, while samples in the upper and lower reaches were collected during the period May 1940 to March 1941. The extent of pollution indicated by the analytical results is as follows:

505. Pittsburgh to Huntington: Dissolved oxygen conditions in this reach of the river were generally good at the time of sampling; the large majority of samples having oxygen demands of less than 3 parts per million and dissolved oxygen contents of more than 6.5 parts per million. However, there were present relatively high concentrations of coliform bacteria, counts in excess of 200 per milliliter being recorded at times at all stations except the three just above Huntington, W. Va. The heaviest pollution was observed below Pittsburgh, Pa., Wheeling, W. Va., and Parkersburg, W. Va., while evidence of natural purification was observed in the 53-mile reach between dam No. 14 below Moundsville, W. Va., and dam No. 17 above Marietta, Ohio, and in the 70 miles between dam No. 23 below Parkersburg, W. Va., and dam No. 27 above Huntington, W. Va.

506. Acid stream conditions were observed as far downstream as dam No. 17 above Marietta, Ohio, during periods of low discharge. The range of pH values was from 4.7 to 6.5.

507. Phenols in excess of 1 part per billion were observed in samples below East Liverpool, Ohio; Steubenville, Ohio; and Wheeling, W. Va.; while concentrations of from 2 to 8 parts per billion were observed at dam No. 14 and dam No. 15 below Moundsville, W. Va.; and dam No. 22 and dam No. 23 below Parkersburg, W. Va.

508. Huntington to Louisville: Dissolved oxygen conditions were generally good in the reach from Huntington, W. Va., to Cincinnati, Ohio. Oxygen demands averaged about 1.0 parts per million and rarely exceeded 2.0 parts per million in this reach. Below Cincinnati, Ohio, decreases in dissolved oxygen content were observed, including minimum monthly average values of 3.8 to 5.4 parts per million. The dissolved oxygen content of individual samples approached zero. Oxygen demand results below Cincinnati, Ohio, were generally less than 3.0 parts per million, although very high values were observed in the immediate vicinity of Cincinnati sewer outlets.

The dissolved oxygen content of the stream increased between dam No. 39 and Louisville, Ky., with a slight depression at Madison, Ind.

509. The major problem in the Huntington-Portsmouth reach is one of high bacterial pollution, mainly of local origin, affecting the quality of raw water used for public supplies. Coliform bacteria counts in excess of 200 per milliliter were observed in 21 percent of the samples above Ashland, Ky., 26 percent of the samples above Ironton, Ohio, and 6 percent of the samples above Cincinnati. A zone of self-purification between Portsmouth and dam No. 36 above Cincinnati was apparent during low-flow periods. Below Cincinnati, coliform averages were from 2,000 to 60,000 per milliliter during periods of low flow. An increase in coliform counts was also observed below Madison, Ind., and was especially marked during the summer months.

510. Phenols in excess of 1 part per billion were recorded at dam No. 27 and dam No. 28, above and below Huntington, respectively, and at dam No. 30 and dam No. 31, above and below Portsmouth, respectively.

511. Louisville to mouth: The zones of most severe pollution in the lower river were found immediately below Louisville, Ky., and in the Evansville, Ind.-Henderson, Ky., area. Lesser sources of pollution are Owensboro, Ky.; Paducah, Ky.; and Cairo, Ill. At the time of sampling, dissolved oxygen conditions throughout the section were good, even below the larger communities. Except for a slight lessening of dissolved oxygen content below Louisville, which was noted in August and October samples, dissolved oxygen remained near or above saturation levels. Oxygen demands were below 3 parts per million for the most part. Coliform bacteria results reached their highest averages in the 10-mile reach below Louisville, and were relatively high below Owensboro, Evansville, and Cairo. Marked evidence of self-purification was indicated in the reach between Louisville and Evansville, and little evidence of pollution was found in the extreme lower portion of the river.

512. *Methods of pollution control.*—The most important problem created by pollution in the Ohio River is the unduly heavy bacterial loading imposed on the community water purification plants along the stream. Other problems are taste and odor difficulties, general lessening of recreational values, occasional destruction of fish life, and nuisance conditions due to discoloration and floating matter in the stream and to occasional oxygen depletion below the largest cities.

513. Primary treatment of all wastes discharged to the Ohio River is suggested. In addition, continuous chlorination of the treatment plant effluents at all of the larger municipalities and at any of the smaller ones whose sewage appreciably affects downstream water intakes, would aid in reducing bacterial loadings at these intakes. Provision for the addition of coagulants during critical periods should also be made at Pittsburgh and Cincinnati. Low flow control provided above Pittsburgh and Cincinnati might eliminate the need for more than primary treatment at these cities. Pittsburgh is the critical location with respect to low flow control, since storage provided above that community in quantity sufficient for organic and acid waste control would be more than ample at downstream localities.

514. Treatment of organic industrial wastes to a degree equivalent to primary sewage treatment should be sufficient, and could be

accomplished in municipal treatment plants, except at industrial establishments whose wastes cause tastes and odors in public water supplies. In the latter instances, special attention should be given. Acid wastes from steel mills should be neutralized, at least during periods when their contribution to the acid load on the stream is significant. Control of acid mine drainage on tributary streams would insure satisfactory conditions on the Ohio River.

515. The cost of a suggested program of pollution control on the main Ohio River is summarized in the following table. Such a program would reduce bacterial loadings, reduce taste and odor troubles in public water supplies, and eliminate nuisance conditions below large sources of pollution. Recreational values would also be enhanced by the improved appearance and quality of the river water, and by the growth of fish life in the stream.

Suggested program of pollution control for the main Ohio River Basin—Economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment: Primary (subtotal)	111	2,018,500	2,170,000	4,253,700	$27,560,000	$1,765,000	$1,940,000	$3,705,000
Interceptors					40,350,000	(1)	1,890,000	1,890,000
Industrial treatment	(2)				3,120,000	705,000	410,000	1,115,000
Mine sealing					(3)	(3)	(3)	(3)
Subtotal					71,030,000	2,470,000	4,240,000	6,710,000
Emergency allowance, 20 percent [4]					14,210,000			
Total					85,240,000			

[1] Negligible.
[2] Includes such items as minor corrections, process changes, sewer construction, treatment plants, etc.
[3] Costs for "main" Ohio River Basin included with those for minor tributary basins.
[4] Estimated additional cost of program if provided during present emergency period.

APPENDIX U

MINOR TRIBUTARY BASINS

SUMMARY

516. *General description.*—Minor tributaries of the Ohio River drain about 23,780 square miles, or approximately 12 percent of the area of the Ohio River Valley. Most of the area drained by these streams is hilly. Agriculture is the predominant occupation, but there are also important coal-mining areas in Pennsylvania, in the West Virginia panhandle and adjacent parts of Ohio, and in the Saline and Tradewater River Basins. There is very little other industrial development. The principal minor tributaries together with their drainage areas are as follows:

Tributary	Point of confluence with Ohio River (miles above mouth of Ohio River)	Drainage area (square miles)
Cache River, Ill	6.3	720
Tradewater River, Ky	107.6	995
Saline River, Ill	113.7	1,235
Blue River, Ind	318.1	466
Brush Creek, Ohio	593.0	435
Little Sandy River, Ky	644.6	780
Twelvepole Creek, W. Va	667.7	441
Raccoon Creek, Ohio	704.9	684
Middle Island Creek, W. Va	827.0	685
Little Beaver River, Ohio-Pa	941.5	510

General maps of the minor tributary basins are shown on plates 3, 6, and 9.

517. The minor tributaries are not navigated commercially and there are no hydroelectric developments in their basins. Urban population has nearly doubled since 1910, while rural population has increased somewhat in the past decade. The present total population of the minor tributary basins is about 1,385,200 of which only 9 percent is urban. Principal communities and their populations (1940 census) are as follows:

Community	Population	Basin
Washington, Pa	26,166	Chartiers Creek.
Canonsburg, Pa	12,599	Do.
Salem, Ohio	12,301	Little Beaver River.
Harrisburg, Ill	11,453	Saline River.
Wellston, Ohio	5,537	Raccoon Creek.
East Palestine, Ohio	5,123	Little Beaver River.
Barnesville, Ohio	5,002	Captina Creek.

518. *Water uses.*—There are 94 public water supplies in the minor tributary basins of the Ohio River of which 44, aggregating about 9.45 million gallons per day and serving 132,600 persons, are from surface sources. About 19 percent of the population using surface supplies is served by 9 supplies subject to pollution from community sewer outfalls. All of these supplies are coagulated, settled, filtered, and chlorinated, and 2 supplies are lime soda softened.

519. Many of the streams, particularly those which are relatively unpolluted and which are readily accessible to residents of the larger Ohio River cities, are used extensively for recreation. Industrial water supply is not a major problem.

520. *Sources of pollution.*—About 167,800 persons, or 12 percent of the population of the minor tributary basins of the Ohio River Valley, are served by sewers. Industrial wastes, after application of various corrective measures now employed, contribute an additional net population equivalent of 31,200 (based on biochemical oxygen demand), of which 900, or about 3 percent, receives further treatment in municipal plants. About 96 percent of the industrial wastes are from canneries and meat-packing plants, most of which are located on small streams in Indiana. Of the 24 plants whose wastes do not receive municipal treatment, 16 have taken at least minor corrective measures toward reducing their pollution of the streams. Twelve primary and 30 secondary municipal waste-treatment plants, in which

about $3,800,000 have been invested, serve 13,900 and 96,400 persons, respectively, and reduce the combined population equivalent of domestic and industrial wastes to about 110,900, as discharged. Summarized data follow:

Waste sources:			
Total population (1940 census)			1,385,202
Sewered population:			
Connected to municipal treatment		110,300	
Not connected to municipal treatment		57,500	
			167,800
Industrial wastes (population equivalent after application of independent corrective measures now in force but prior to other treatment):			
Connected to municipal treatment		900	
Not connected to municipal treatment:			
Canning	13,300		
Meat	16,700		
Milk	300		
		30,300	
			31,200
Total (population equivalent)			199,000
Wastes as discharged:			
Human wastes (sewered) (population equivalent after all present treatment):			
Connected to municipal treatment		23,000	
Not connected to municipal treatment		57,500	
			80,500
Industrial wastes (population equivalent after all present treatment):			
Connected to municipal treatment		100	
Not connected to municipal treatment		30,300	
			30,400
Total waste residual (population equivalent)			110,900

NOTE.—Single industries of a specific classification are included within the miscellaneous classification.

521. Acid mine drainage is the most damaging pollutant to which the minor tributaries of the Ohio River are subjected. This waste adversely affects streams in the upper part of the basin, particularly above Marietta, Ohio, and in the Saline and Tradewater River Basins in the lower part of the Ohio River Valley. Mine sealing has reduced the original acid load by about 23 percent, leaving a present load of about 176,500 tons per year (calcium carbonate equivalent).

522. *Extent of pollution.*—During the period from February 1939 to March 1941 the Public Health Service collected and analyzed more than 1,000 samples from 125 stations in the minor tributary basins. Sampling was done concurrently with work on adjacent sections of the main Ohio River. Streams in the middle reaches of the basin were sampled from February 1939 to April 1940 and those in the upper and lower reaches were sampled from May 1940 to March 1941.

523. *Pittsburgh to Huntington.*—Oxygen conditions were generally good except on Chartiers Creek below Washington, and Canonsburg, Pa., and on some of the very small tributaries. Coliform bacteria counts were generally high as on the main stream. A number of the minor tributaries in this area were heavily acid.

524. *Huntington to Louisville.*—Oxygen conditions were generally good throughout the region with dissolved oxygen results above 6.5 parts per million and biochemical oxygen demand results below 3 parts per million. Moderately high coliform bacteria counts were

found below small sources of pollution on tributaries between Huntington, W. Va., and Cincinnati, Ohio, and local pollution was evidenced on Laughery Creek at Batesville, Ind., Hogan Creek at Aurora, Ind., Harrods Creek at La Grange, Ky., and Goose Creek at Anchorage, Ky.

525. *Louisville to Mouth.*—The minor tributaries in this section were in good sanitary condition, except in the Saline and Tradewater River basins, where local pollution was observed at several points. Low dissolved oxygen content, high biochemical oxygen demand, and high coliform bacteria counts were found below Eldorado and Harrisburg, Ill., in the Saline River Basin. Several tributaries of the Saline River were found to be acid, with pH values ranging from 2.8 to 4.3. In the Tradewater River basin, local pollution was observed at Dawson Springs, Sturgis, and Providence, Ky., and acid conditions were found at Providence and Earlington, Ky., with pH values ranging from 3.3 to 5.7.

526. Plates 3, 4, 5, 6, 7, 8, 9, 10, and 11 include data on sources of pollution, and on coliform bacteria and dissolved oxygen results for the minor tributary basins.

527. *Methods of pollution control.*—Pollution problems on minor tributaries of the Ohio River are predominately local in nature and are concerned primarily with prevention or correction of nuisance conditions in small streams subject to extremely low flows. The low flows to which the streams are subject make secondary waste treatment necessary in most cases. Continuation of the mine-sealing program would aid in reducing the mine acid load on the streams.

528. The cost of a suggested program of pollution control is shown in the following table. The program would eliminate local nuisance, improve streams for use as public water supplies, and preserve and enhance recreational facilities.

Suggested program of pollution control for the minor tributary basins—economic aspects

Suggested pollution control measures		Population			Estimated cost			
						Annual		
Type	Number	Now sewered	1940 census	Design	Capital	Operation and maintenance	Amortization and interest	Total
Municipal treatment:								
Primary	17	73,600	45,400	50,300	$520,000	$27,000	$37,000	$64,000
Secondary	23	22,800	39,800	45,000	830,000	40,000	58,000	98,000
Improvements	5	3,900	7,400		70,000	3,000	5,000	8,000
Subtotal	45	100,300	92,600		1,420,000	70,000	100,000	170,000
Interceptors					890,000	(1)	40,000	40,000
Industrial treatment	(2)				280,000	40,000	35,000	75,000
Mine sealing	(3)				[4] 480,000	[4] 52,000	[4] 20,000	[4] 72,000
Subtotal					3,070,000	162,000	195,000	357,000
Emergency allowance, 20 percent [5]					610,000			
Total					3,680,000			

[1] Negligible.
[2] Includes such items as minor corrections, process changes, sewer construction, treatment plants, etc.
[3] Minor tributary and "main" Ohio River basins combined.
[4] Initial program contemplates sealing of 77,756 ton-years of acid. See note 3.
[5] Estimated additional cost of program if provided during present emergency period.

WAR DEPARTMENT

CORPS OF ENGINEERS, U.S. ARMY

PLATE NO. 1

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

GENERAL MAP

OHIO RIVER BASIN

IN 1 SHEET — SHEET NO. 1 — SCALES AS SHOWN

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

PLATE PREPARED: APRIL 1, 1943

GPO-43 O-90035

PLATE NO. 2

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

SOURCES OF POLLUTION

OHIO RIVER BASIN

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

10 0 10 20 30
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED APRIL 1, 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE
GPO-43 0-90035

PLATE NO. 3

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

SOURCES OF POLLUTION
OHIO RIVER & MINOR TRIBUTARY BASINS
PITTSBURGH TO HUNTINGTON

IN 1 SHEET | SHEET NO. 1 | SCALE AS SHOWN

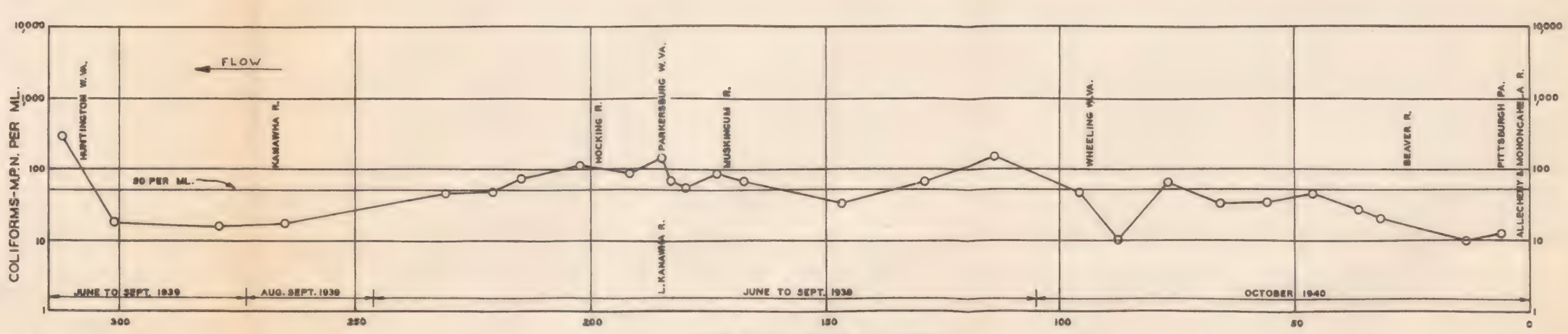
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

PLATE PREPARED APRIL 1, 1943

GPO-43 O-80835



NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILE SHOWS SELECTED MONTHLY AVERAGE RESULTS AS INDICATED
(3) SAMPLING PERIOD REPRESENTED JUNE 1939 TO MARCH 1941

OHIO RIVER AND MINOR TRIBUTARY BASINS
PITTSBURGH TO HUNTINGTON

PLATE NO. 4

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

COLIFORM BACTERIA RESULTS
OHIO RIVER AND MINOR TRIBUTARY BASINS
PITTSBURGH TO HUNTINGTON

IN 1 SHEET | SHEET NO 1 | SCALE AS SHOWN

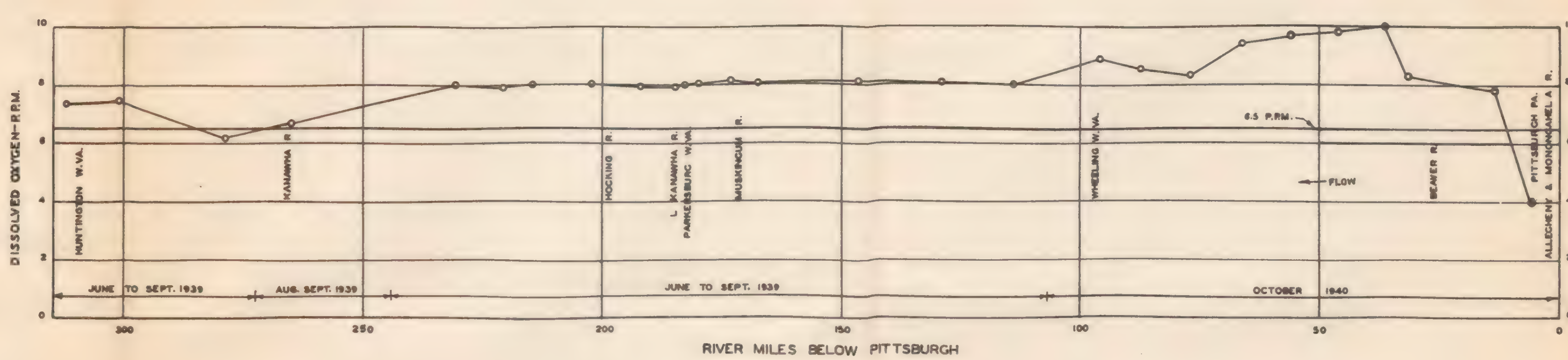
10 0 10 20
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

MAP PREPARED U.S. PUBLIC HEALTH SERVICE

PLATE PREPARED APRIL 1941

GPO-43 O-00035



NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS
(2) PROFILE SHOWS SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIOD REPRESENTED JUNE, 1939 TO MARCH, 1941.

OHIO RIVER AND MINOR TRIBUTARY BASINS
PITTSBURGH TO HUNTINGTON

PLATE NO. 5

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

DISSOLVED OXYGEN RESULTS
OHIO RIVER AND MINOR TRIBUTARY BASINS
PITTSBURGH TO HUNTINGTON

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

10 0 10 20
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED APRIL 1942

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE.

GPO-43 O-00035

PLATE NO. 6

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

SOURCES OF POLLUTION

OHIO RIVER AND MINOR TRIBUTARY BASINS

HUNTINGTON TO LOUISVILLE

IN 1 SHEET — SHEET NO. 1 — SCALE: AS SHOWN

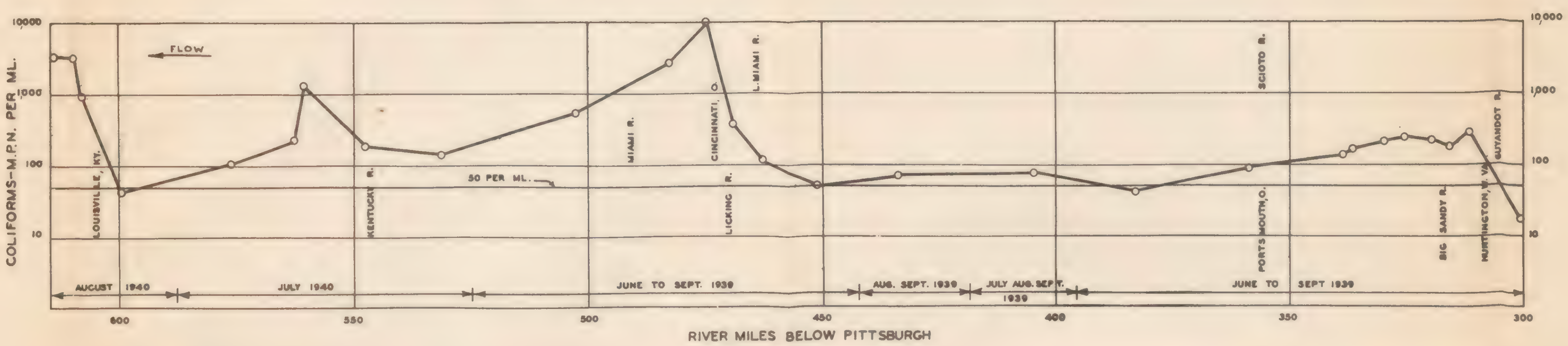
10 0 10
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED APRIL 1, 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

GPO-43 O-98835



NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILE SHOWS SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIODS REPRESENTED JANUARY, 1939 TO MARCH, 1940; JULY, OCTOBER, 1940; JANUARY, 1941

OHIO RIVER AND MINOR TRIBUTARY BASINS
HUNTINGTON TO LOUISVILLE

PLATE NO. 7

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

COLIFORM BACTERIA RESULTS
OHIO RIVER AND MINOR TRIBUTARY BASINS
HUNTINGTON TO LOUISVILLE

IN 1 SHEET — SHEET NO. 1 — SCALES AS SHOWN

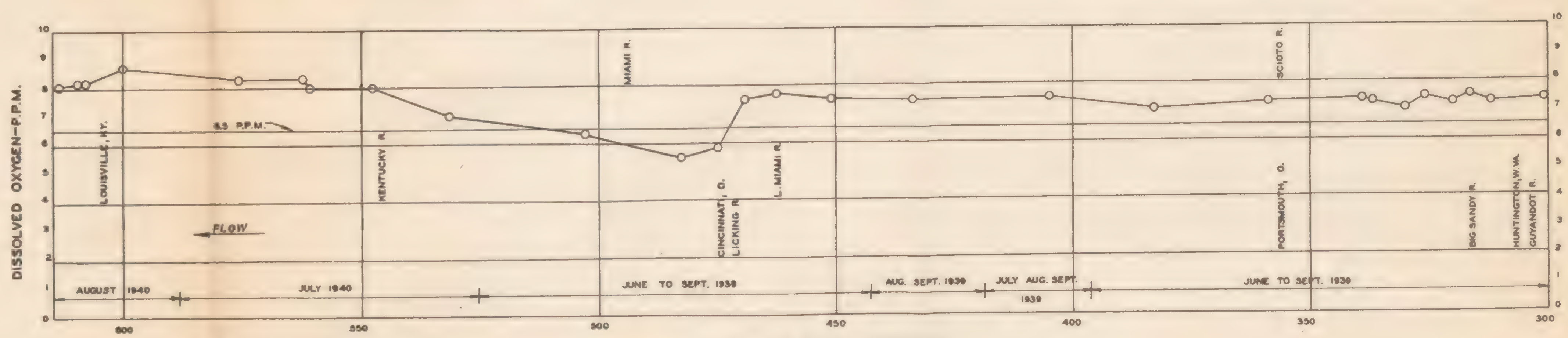
10 0 10 20
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

MAP PREPARED BY U. S. PUBLIC HEALTH SERVICE

PLATE PREPARED APRIL 1, 1943

GPO-43 O-80035



NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILE SHOWS SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIOD REPRESENTED JANUARY, 1939 TO MARCH, 1940; JULY, OCTOBER, 1940; JANUARY, 1941

OHIO RIVER AND MINOR TRIBUTARY BASINS
HUNTINGTON TO LOUISVILLE

PLATE NO. 8

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

DISSOLVED OXYGEN RESULTS
OHIO RIVER AND MINOR TRIBUTARY BASINS
HUNTINGTON TO LOUISVILLE

IN 1 SHEET — SHEET NO. 1 — SCALES AS SHOWN

10 0 10 20
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED APRIL 1, 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE.

GPO-43 O-98835

WAR DEPARTMENT

CORPS OF ENGINEERS, U.S. ARMY

PLATE NO. 9

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

SOURCES OF POLLUTION

OHIO RIVER AND MINOR TRIBUTARY BASINS

LOUISVILLE TO MOUTH

IN 1 SHEET — SHEET NO. 1 — SCALE: AS SHOWN

10 0 10

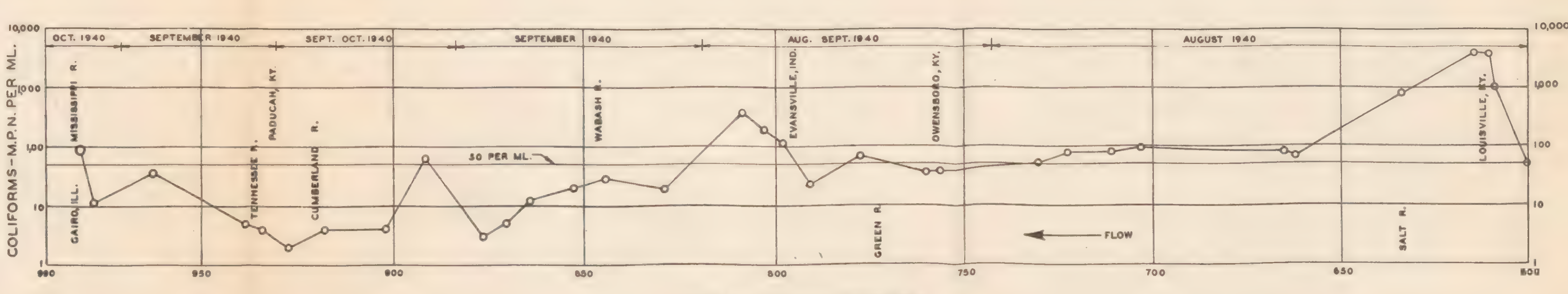
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED APRIL 1, 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

GPO-43 0-80035



NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILE SHOWS SELECTED MONTHLY AVERAGE RESULTS AS INDICATED
(3) SAMPLING PERIOD REPRESENTED JULY TO NOVEMBER, 1940 JANUARY TO MARCH, 1941

OHIO RIVER AND MINOR TRIBUTARY BASINS
LOUISVILLE TO MOUTH

PLATE NO. 10

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

COLIFORM BACTERIA RESULTS
OHIO RIVER AND MINOR TRIBUTARY BASINS
LOUISEVILLE TO MOUTH

IN 1 SHEET — SHEET NO. 1 — SCALES AS SHOWN

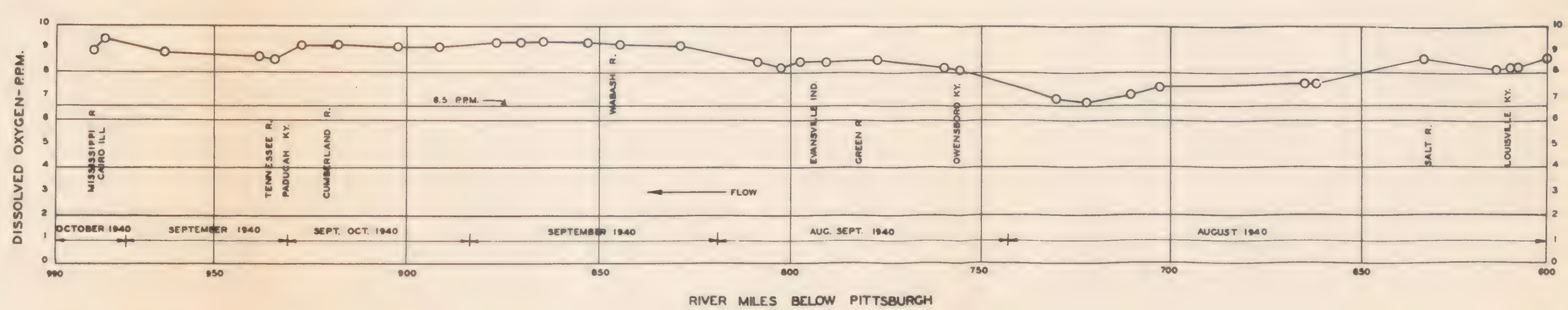
10 0 10 20
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED APRIL 1, 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERIVCE.

GPO-43 O-80035



NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILE SHOWS SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIOD REPRESENTED JULY TO NOVEMBER, 1940; JANUARY TO MARCH, 1941.

OHIO RIVER AND MINOR TRIBUTARY BASINS
LOUISVILLE TO MOUTH

PLATE NO. 11

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

DISSOLVED OXYGEN RESULTS
OHIO RIVER AND MINOR TRIBUTARY BASINS
LOUISVILLE TO MOUTH

IN 1 SHEET — SHEET NO. 1 — SCALES AS SHOWN

SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

PLATE PREPARED APRIL 1, 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

GPO-43 0-90035

PLATE NO. 12

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

SOURCES OF POLLUTION

ALLEGHENY RIVER BASIN

IN 1 SHEET — SHEET NO. 1 — SCALE: AS SHOWN

10 0 10 20

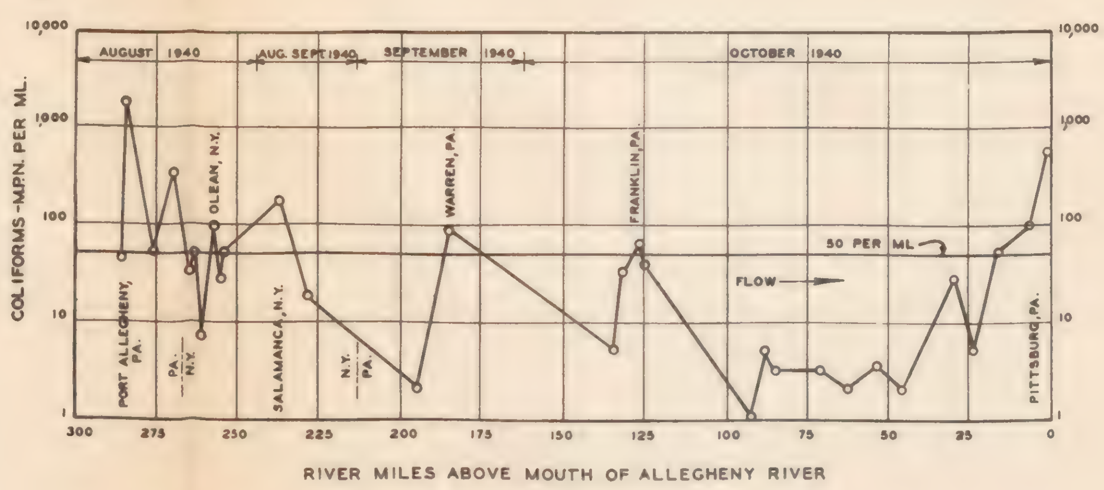
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED APRIL 1, 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

GPO-43 O-80035



NOTES:

(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.

(2) PROFILE SHOWS SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.

(3) SAMPLING PERIODS REPRESENTED JULY TO DECEMBER 1940

ALLEGHENY RIVER BASIN

PLATE NO. 13

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

COLIFORM BACTERIA RESULTS ALLEGHENY RIVER BASIN

IN 1 SHEET | SHEET NO. 1 | SCALES AS SHOWN

10 0 10 20

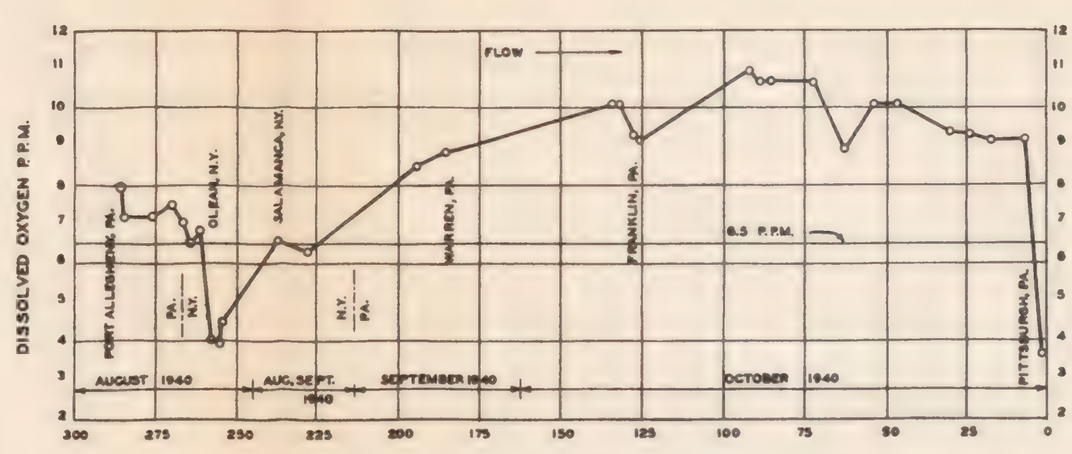
SCALE OF MILES

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

PLATE PREPARED APRIL 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

GPO-43 O-90035



ALLEGHENY RIVER BASIN

NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILE SHOWS SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIOD REPRESENTED JULY TO DECEMBER, 1940.

PLATE NO. 14

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

DISSOLVED OXYGEN RESULTS
ALLEGHENY RIVER BASIN

IN 1 SHEET — SHEET NO. 1 — SCALES AS SHOWN

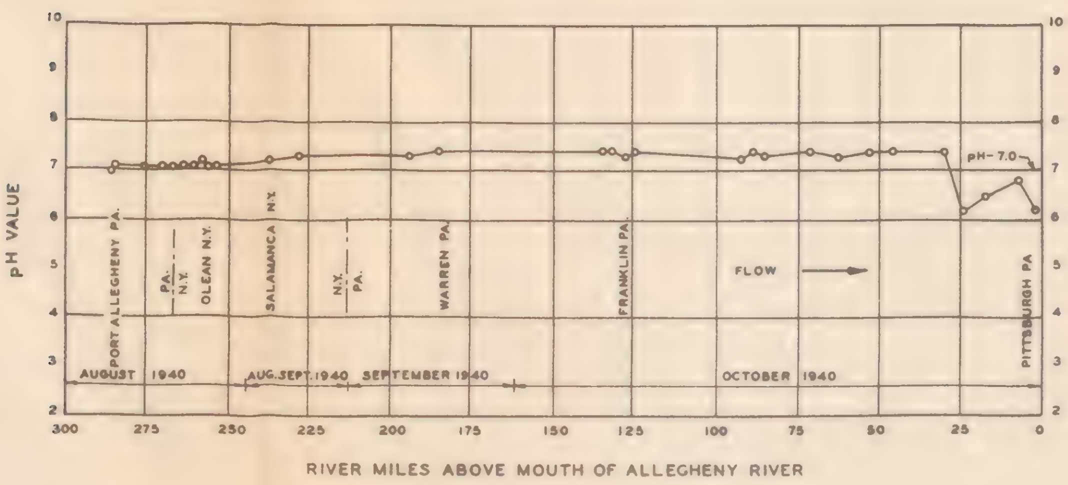
10 0 10 20
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED APRIL 1, 1943

MAP PREPARED BY U. S. PUBLIC HEALTH SERVICE

GPO-43 O-90035



NOTES:

(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS

(2) PROFILE SHOWS SELECTED MONTHLY AVERAGE RESULTS AS INDICATED

(3) SAMPLING PERIOD REPRESENTED JULY TO DECEMBER 1940

ALLEGHENY RIVER BASIN

PLATE NO. 15

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

pH RESULTS
ALLEGHENY RIVER BASIN

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

10 0 10 20
SCALE OF MILES

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

PLATE PREPARED APRIL 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

GPO-43 O-98035

PLATE NO. 16

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

SOURCES OF POLLUTION
MONONGAHELA RIVER BASIN

IN 1 SHEET — SHEET NO. 1 — SCALE: AS SHOWN

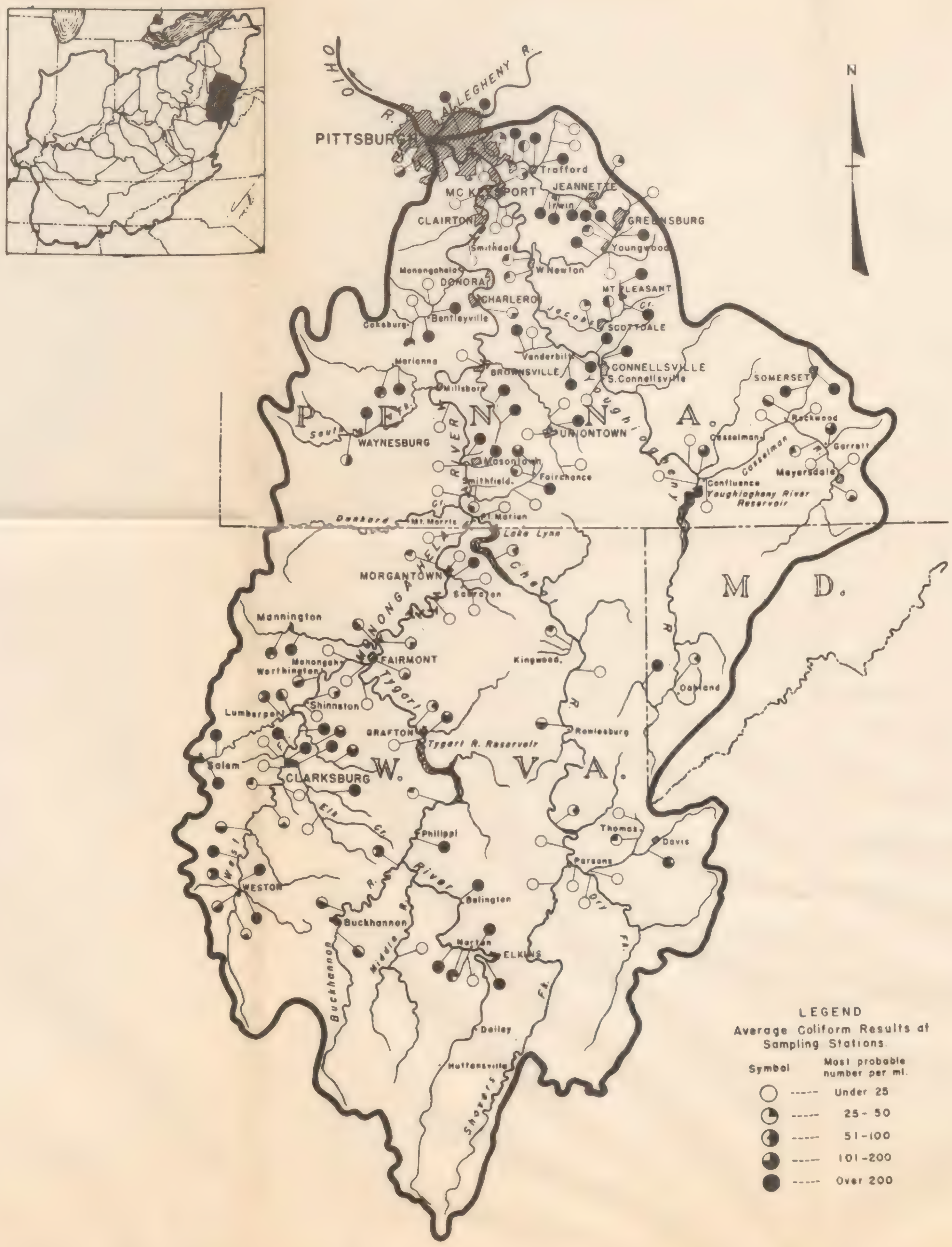
10 0 10
SCALE OF MILES

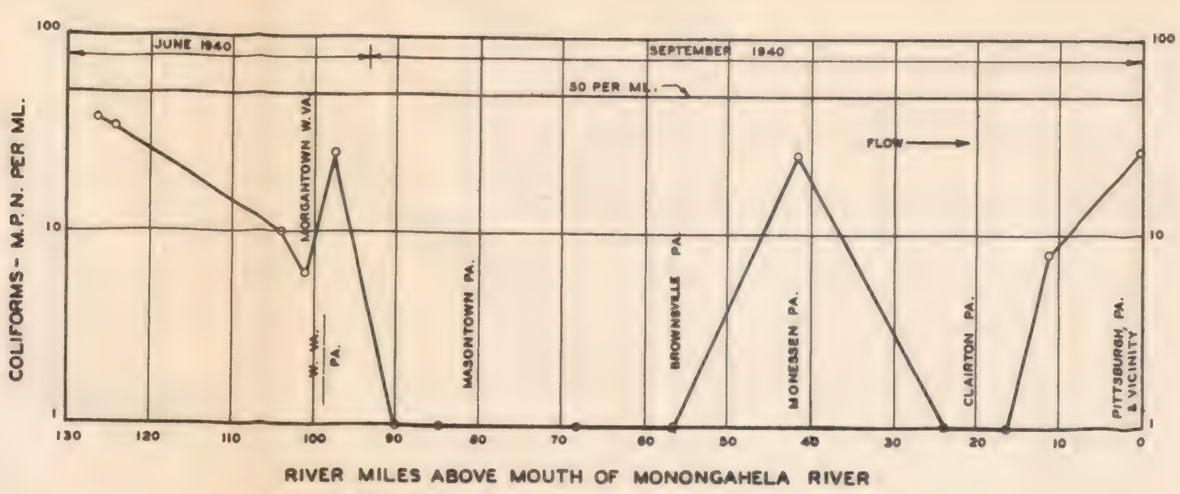
TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

PLATE PREPARED APRIL 1, 1943

GPO-43 O-90035





MONONGAHELA RIVER

NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILE SHOWS SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIOD REPRESENTED: MAY TO DECEMBER 1940

PLATE NO. 17

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

COLIFORM BACTERIA RESULTS

MONOGAHELA RIVER BASIN

IN 1 SHEET — SHEET NO. 1 — SCALES AS SHOWN

10 0 10 20

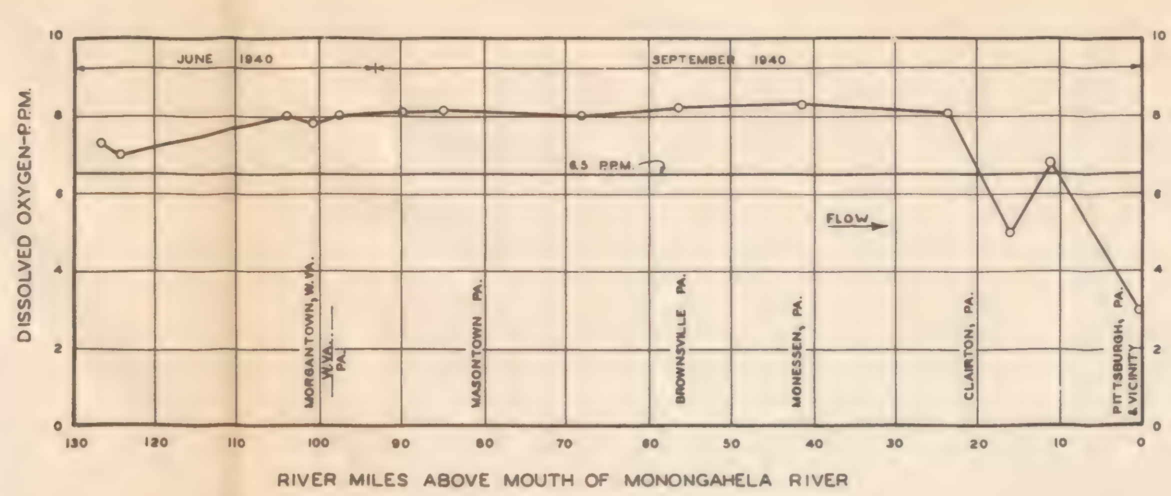
SCALE OF MILES

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

PLATE PREPARED APRIL 1, 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

GPO-43 O-90035



MONONGAHELA RIVER BASIN

NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILE SHOWS SELECTED MONTHLY AVERAGE RESULTS AS INDICATED
(3) SAMPLING PERIOD REPRESENTED: MAY TO DECEMBER 1940

PLATE NO. 18

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

DISSOLVED OXYGEN RESULTS
MONOGAHELA RIVER BASIN

IN 1 SHEET SHEET NO. 1 SCALE AS SHOWN

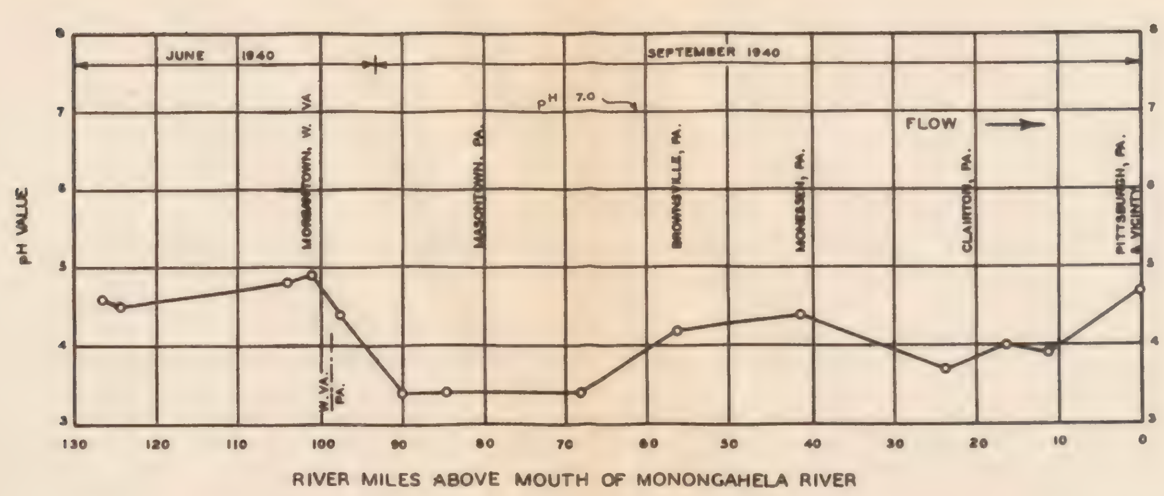
10 0 10 20
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

PLATE PREPARED APRIL 1, 1943

GPO-43 O-90035



MONONGAHELA RIVER BASIN

NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILE SHOWS SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIOD REPRESENTED: MAY TO DECEMBER 1940

PLATE NO. 19

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

pH RESULTS

MONOGAHELA RIVER BASIN

IN 1 SHEET — SHEET NO. 1 — SCALES AS SHOWN

10 0 10 20

SCALE OF MILES

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

PLATE PREPARED: APRIL 1, 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERIVCE.

GPO-43 O-88835

WAR DEPARTMENT

CORPS OF ENGINEERS, U.S. ARMY

PLATE NO. 20

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

SOURCES OF POLLUTION

BEAVER RIVER BASIN

IN 1 SHEET | SHEET NO. 1 | SCALE: AS SHOWN

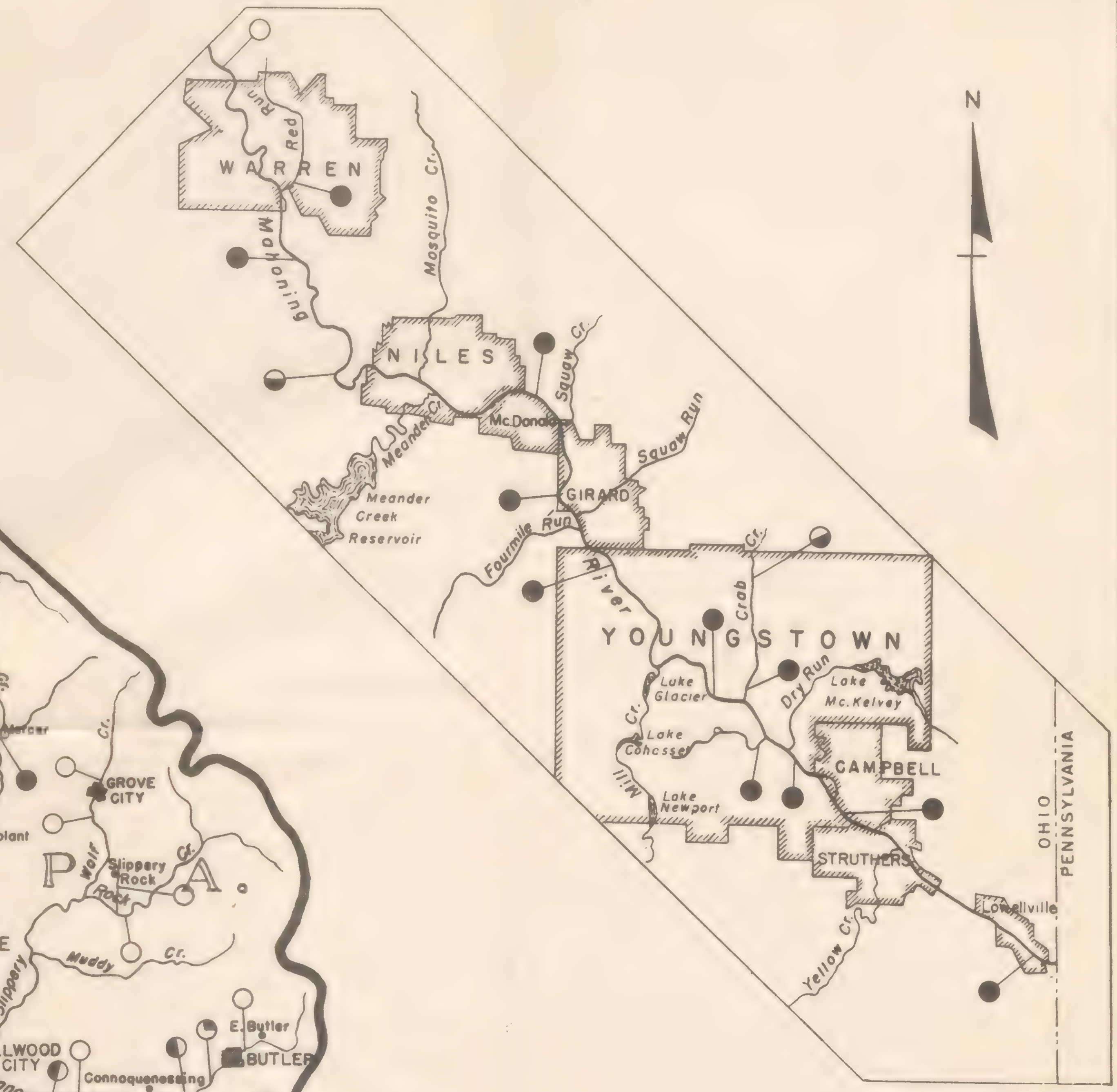
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED APRIL 1, 1943

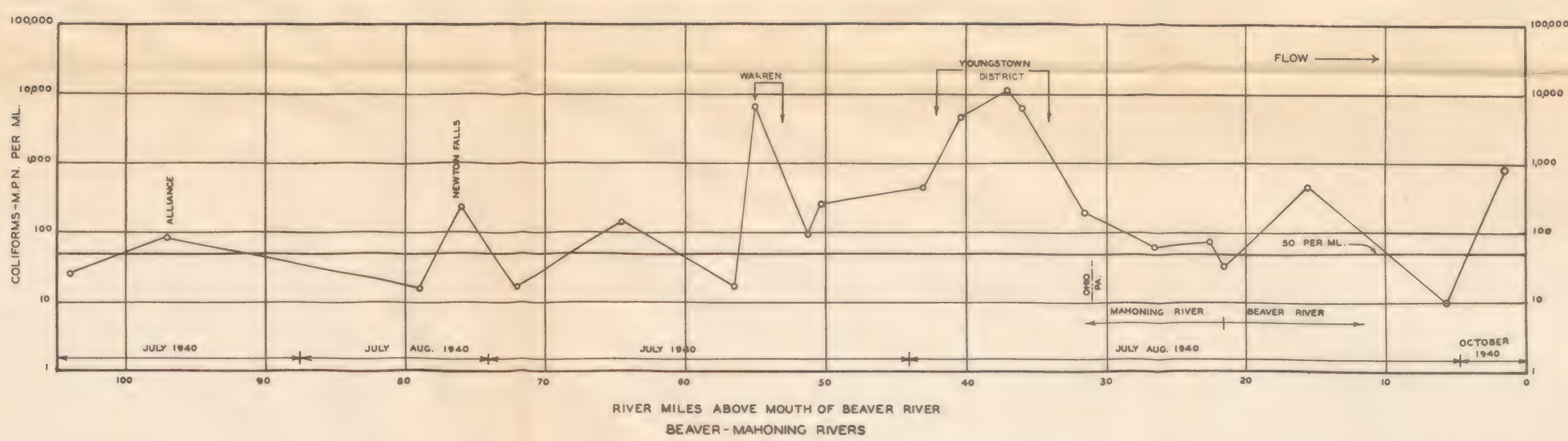
MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

GPO-43 O-80035

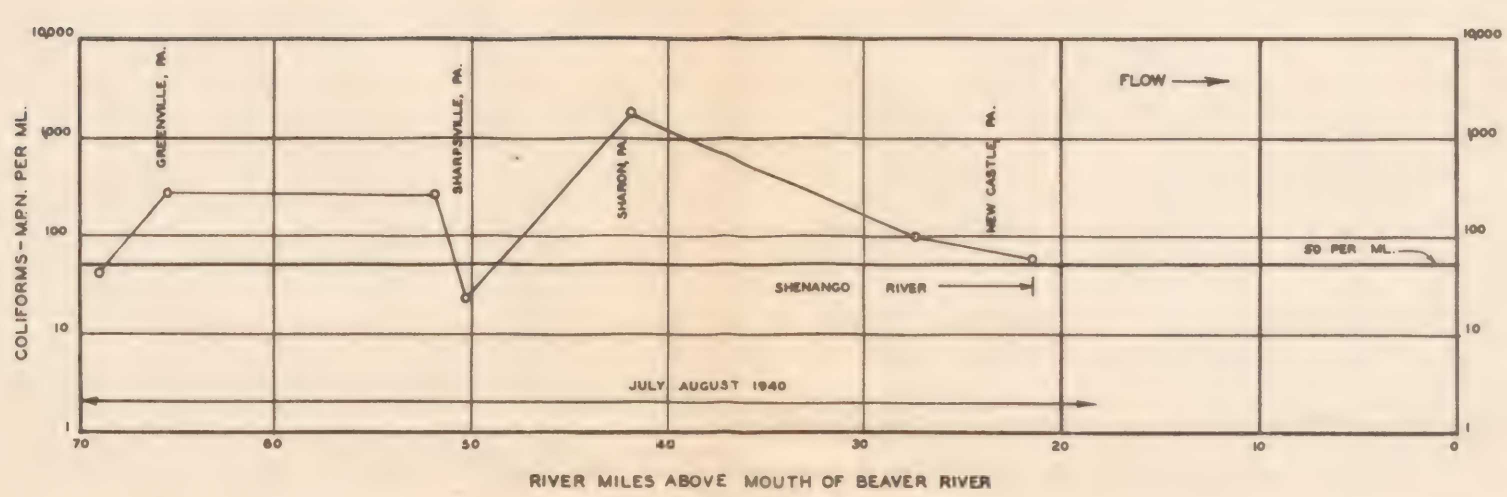


LEGEND
Average Coliform Results at Sampling Stations

Symbol	Most probable number per ml.
○	Under 25
◔	25 - 50
◑	51 - 100
◕	101 - 200
●	Over 200



NOTES:
(1) MAPS SHOW AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILES SHOW SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIODS REPRESENTED JUNE TO AUGUST, 1940.
OCTOBER, 1940 TO JANUARY, 1941.



BEAVER RIVER BASIN

PLATE NO. 21

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL
COLIFORM BACTERIA RESULTS
BEAVER RIVER BASIN

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

5 0 5 10
SCALE OF MILES

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

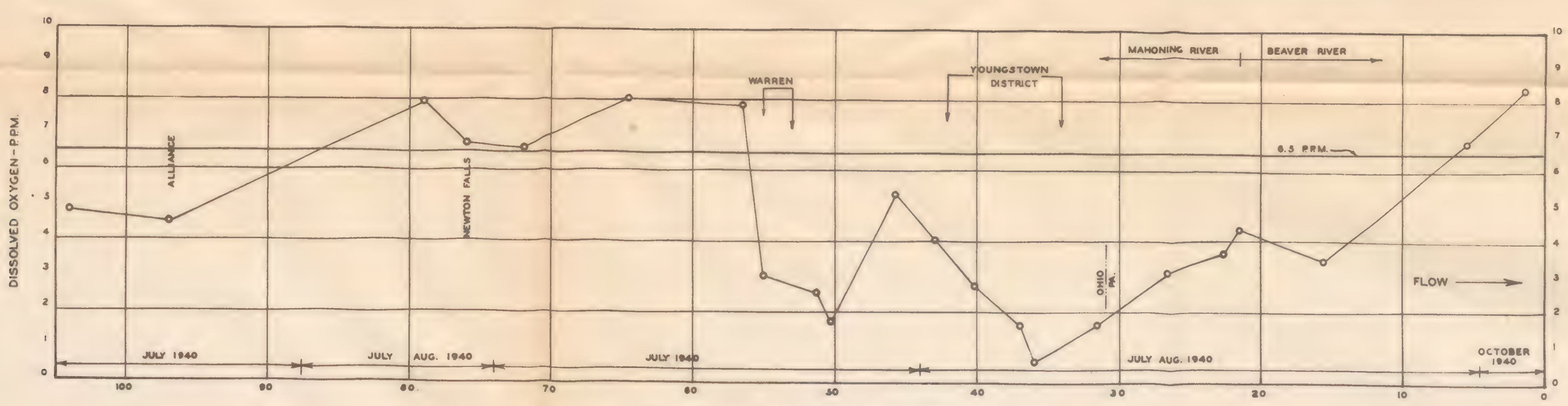
PLATE PREPARED JUNE 1, 1942

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

GPO-41 O-90035

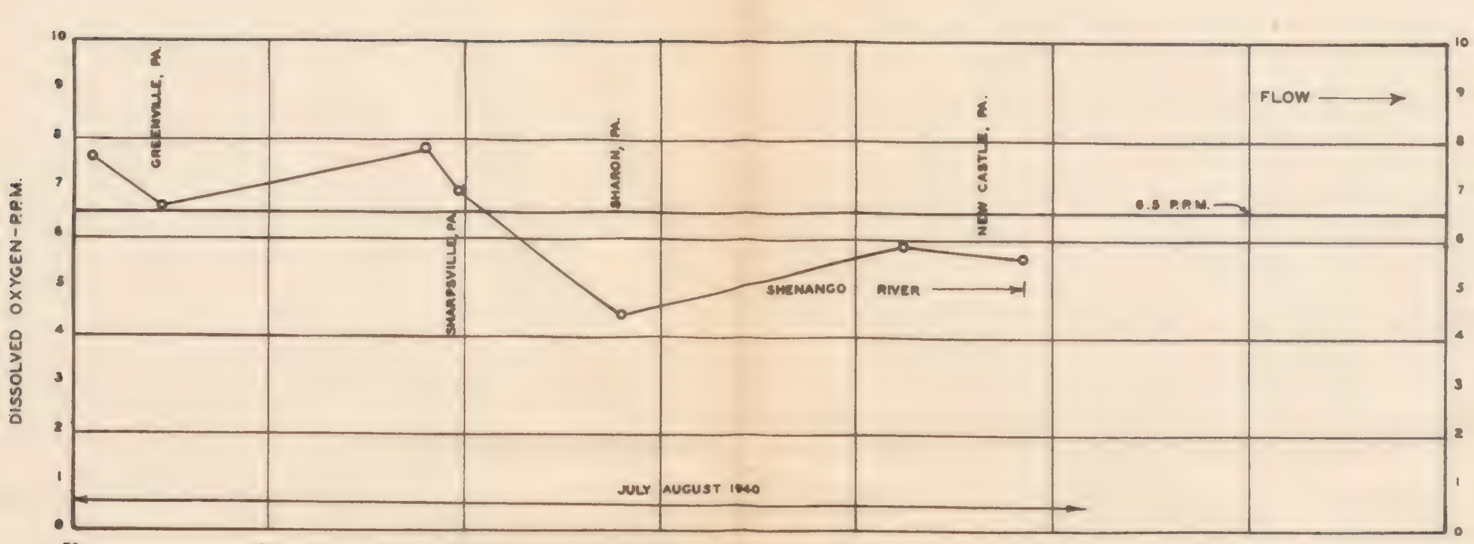
LEGEND
Average Dissolved Oxygen
Results at Sampling Stations.

Symbol	Dissolved Oxygen p.p.m.
○	Over 6.5
◔	5.1 to 6.5
◑	3.1 to 5.0
●	0.1 to 3.0
◉	0.0



RIVER MILES ABOVE MOUTH OF BEAVER RIVER
BEAVER-MAHONING RIVERS

NOTES:
(1) MAPS SHOW AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILES SHOW SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIODS REPRESENTED JUNE TO AUGUST, 1940. OCTOBER, 1940 TO JANUARY, 1941.



RIVER MILES ABOVE MOUTH OF BEAVER RIVER
SHENANGO RIVER

BEAVER RIVER BASIN

PLATE NO 22

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL
DISSOLVED OXYGEN RESULTS
BEAVER RIVER BASIN

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

5 0 5 10
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

MAP PREPARED BY U. S. PUBLIC HEALTH SERVICE

PLATE PREPARED JUNE 1, 1942

GPO-43 O-80035

PLATE NO. 23

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

SOURCES OF POLLUTION

MUSKINGUM - HOCKING RIVER BASINS

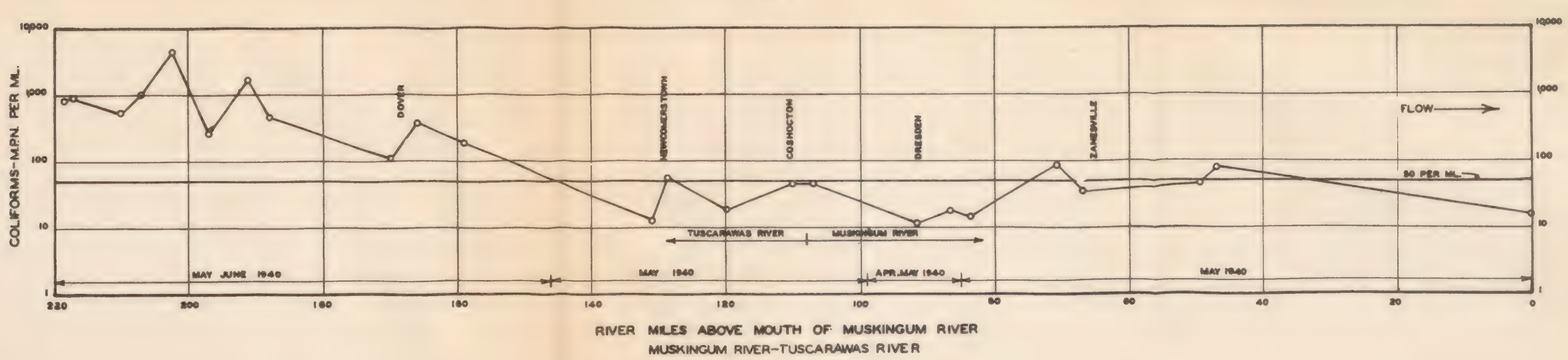
IN 1 SHEET | SHEET NO. 1 | SCALE: AS SHOWN

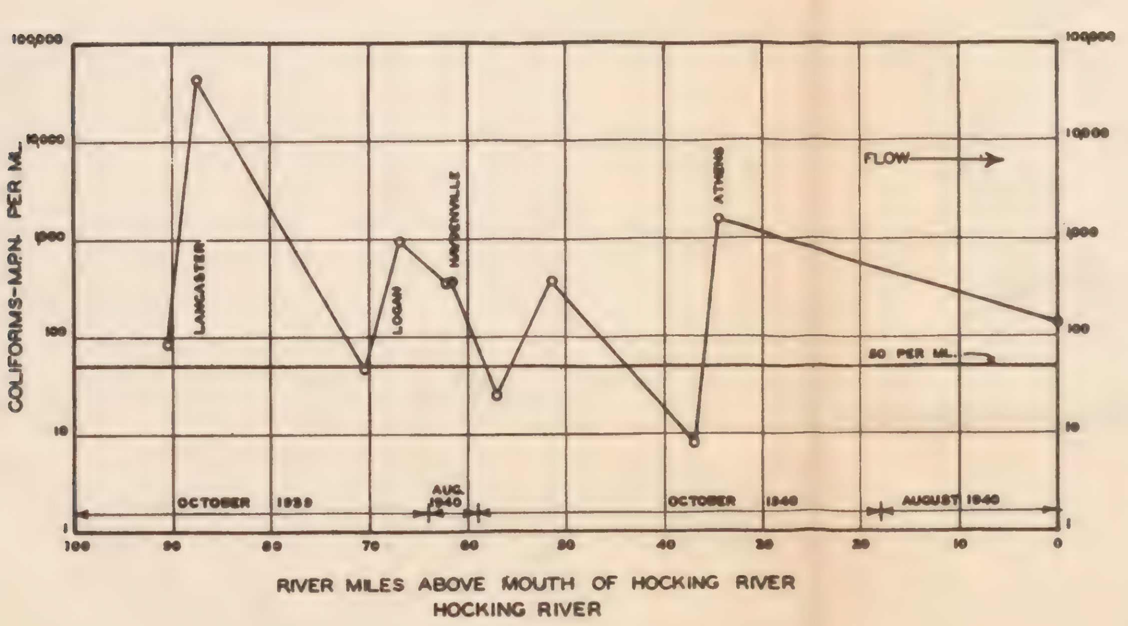
10 0 10 20

SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED APRIL 1, 1943





MUSKINGUM-HOCKING RIVER BASINS

NOTES:-

(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.

(2) PROFILES SHOW SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.

(3) SAMPLING PERIODS REPRESENTED:
MUSKINGUM RIVER-
APRIL TO SEPTEMBER, 1940
JANUARY TO MARCH, 1941
HOCKING RIVER-
OCTOBER AND NOVEMBER, 1939
JANUARY, 1941

PLATE NO 24

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

COLIFORM BACTERIA RESULTS

MUSKINGUM-HOCKING RIVER BASINS

IN 1 SHEET | SHEET NO. 1 | SCALE AS SHOWN

SCALE OF MILES

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

PLATE PREPARED JUNE 1, 1942

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

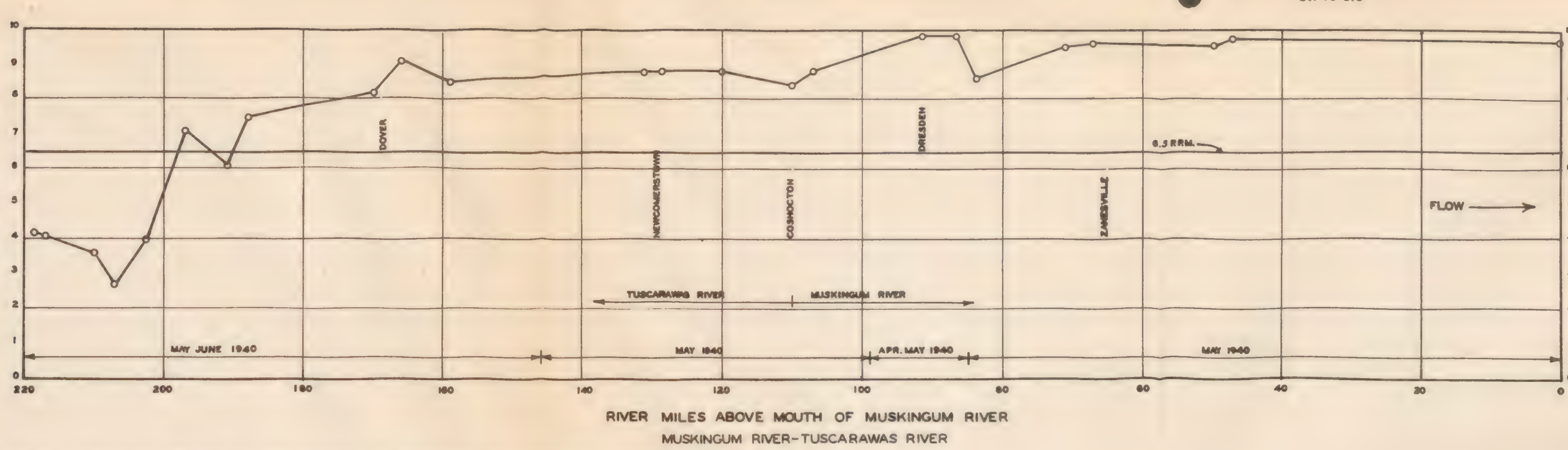
GPO-43 O-88835

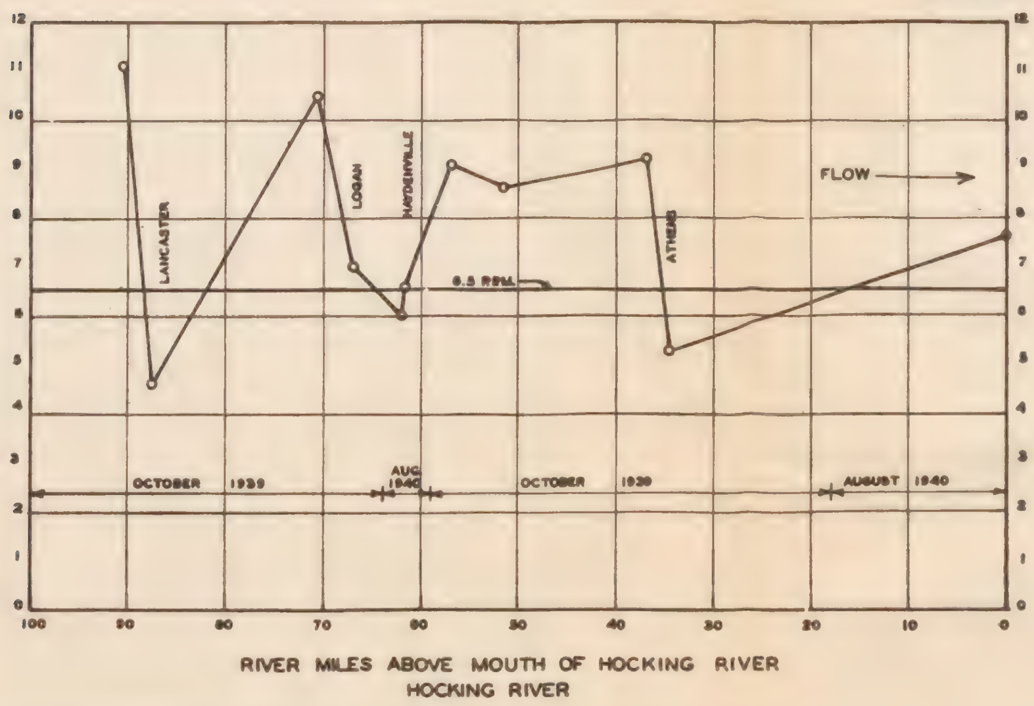
Muskingum Conservancy Reservoirs

1 Atwood
2 Beach City
3 Bolivar
4 Charles Mill
5 Clendening
6 Dover
7 Leesville
8 Mohawk
9 Mohicanville
10 Piedmont
11 Pleasant Hill
12 Senecaville
13 Tappan
14 Wills Creek

LEGEND
Average Dissolved Oxygen
Results at Sampling Stations.

Symbol	Dissolved Oxygen p.p.m.
○	----- Over 6.5
◔	----- 5.1 to 6.5
◑	----- 3.1 to 5.0
●	----- 0.1 to 3.0





MUSKINGUM-HOCKING RIVER BASINS

NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILES SHOW SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIODS REPRESENTED
MUSKINGUM RIVER-
APRIL TO SEPTEMBER, 1940
JANUARY TO MARCH, 1941
HOCKING RIVER-
OCTOBER AND NOVEMBER, 1939
APRIL TO SEPTEMBER, 1940;
JANUARY, 1941

PLATE NO. 25

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

DISSOLVED OXYGEN RESULTS
MUSKINGUM-HOCKING RIVER BASINS

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

SCALE OF MILES: 5 0 5 10

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED JUNE 1, 1942.

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

PLATE NO 26

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

SOURCES OF POLLUTION

LITTLE KANAWHA-KANAWHA RIVER BASINS

IN 1 SHEET | SHEET NO. 1 | SCALE AS SHOWN

10 0 10 20

SCALE OF MILES

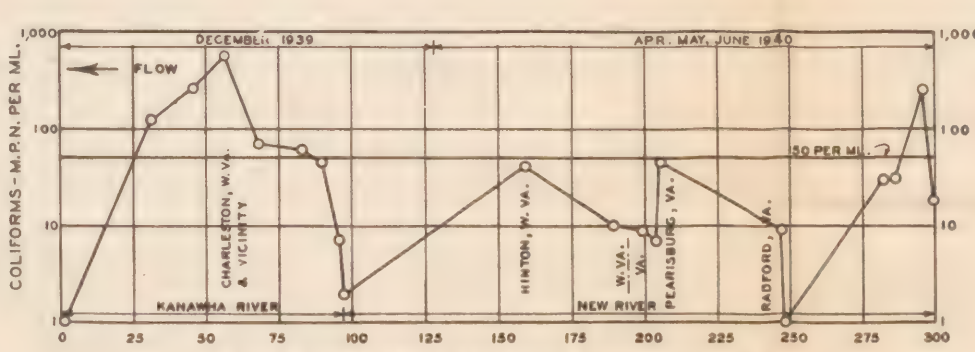
TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

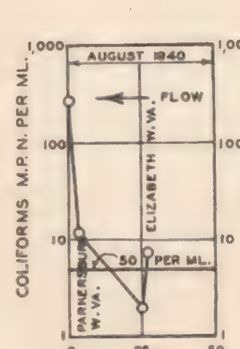
PLATE PREPARED APRIL 1, 1943

PREPARED BY U.S. PUBLIC HEALTH SERVICE

GPO-43 O-90035

NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILES SHOW SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIODS REPRESENTED:
LITTLE KANAWHA RIVER- MAY TO SEPTEMBER, 1940 JANUARY TO MARCH, 1941
KANAWHA RIVER AUGUST, 1939 TO JUNE, 1940 FEBRUARY, 1941





LITTLE KANAWHA-KANAWHA RIVER BASINS

PLATE NO. 27

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

COLIFORM BACTERIA RESULTS
LITTLE KANAWHA- KANAWHA RIVER BASINS

IN 1 SHEET SHEET NO. 1 SCALES AS SHOWN

10 0 10 20
SCALE OF MILES

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

PLATE PREPARED APRIL 1, 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

GPO-43 O-90035

LEGEND

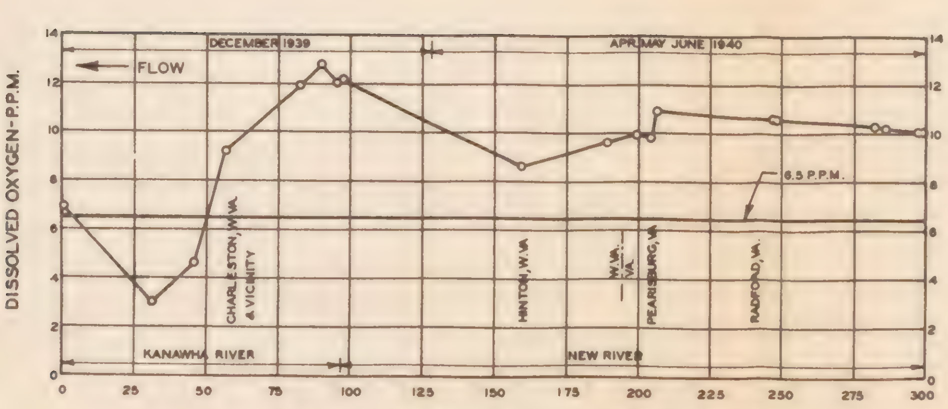
Average Dissolved Oxygen
Results at Sampling Stations.

Symbol	Dissolved Oxygen p.p.m.
○	Over 6.5
◔	5.1 to 6.5
◑	3.1 to 5.0
●	3.0 or less

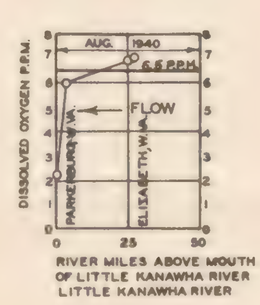
NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.

(2) PROFILES SHOW SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.

(3) SAMPLING PERIODS RERRESENTED:
LITTLE KANAWHA RIVER—
MAY TO SEPTEMBER, 1940
JANUARY TO MARCH, 1941
KANAWHA RIVER
AUGUST, 1939 TO JUNE, 1940
FEBRUARY, 1941



RIVER MILES ABOVE MOUTH OF KANAWHA RIVER
KANAWHA—NEW RIVER



RIVER MILES ABOVE MOUTH
OF LITTLE KANAWHA RIVER
LITTLE KANAWHA RIVER

LITTLE KANAWHA-KANAWHA RIVER BASINS

PLATE NO. 28

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

DISSOLVED OXYGEN RESULTS

LITTLE KANAWHA-KANAWHA RIVER BASINS

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

10 0 10 20
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED APRIL 1, 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE.

GPO-43 D-90035

PLATE NO. 29

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

SOURCES OF POLLUTION

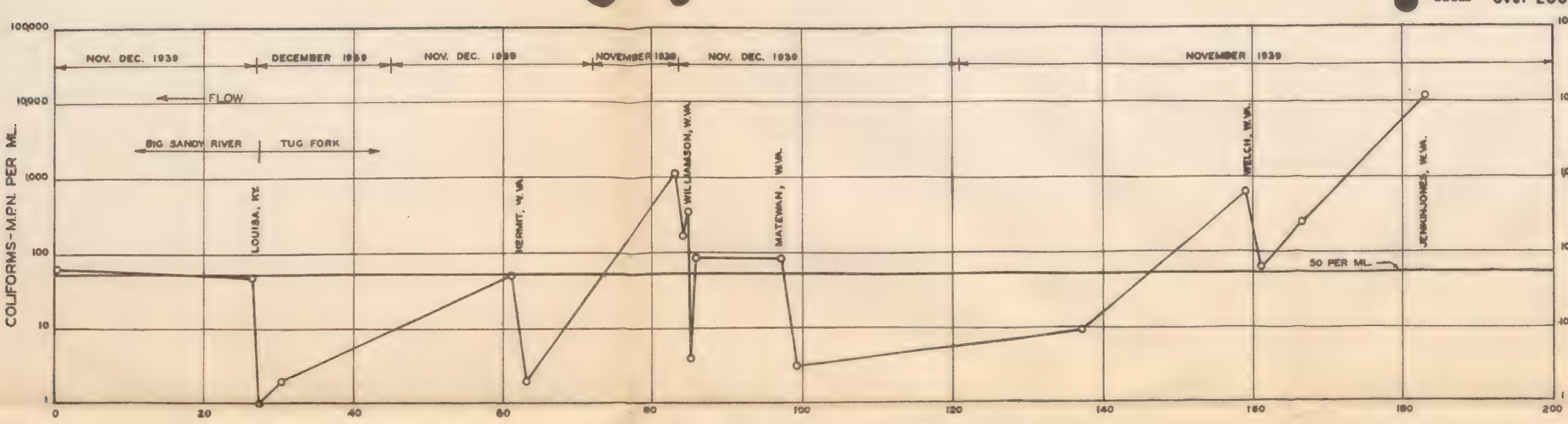
GUYANDOT-BIG SANDY RIVER BASINS

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

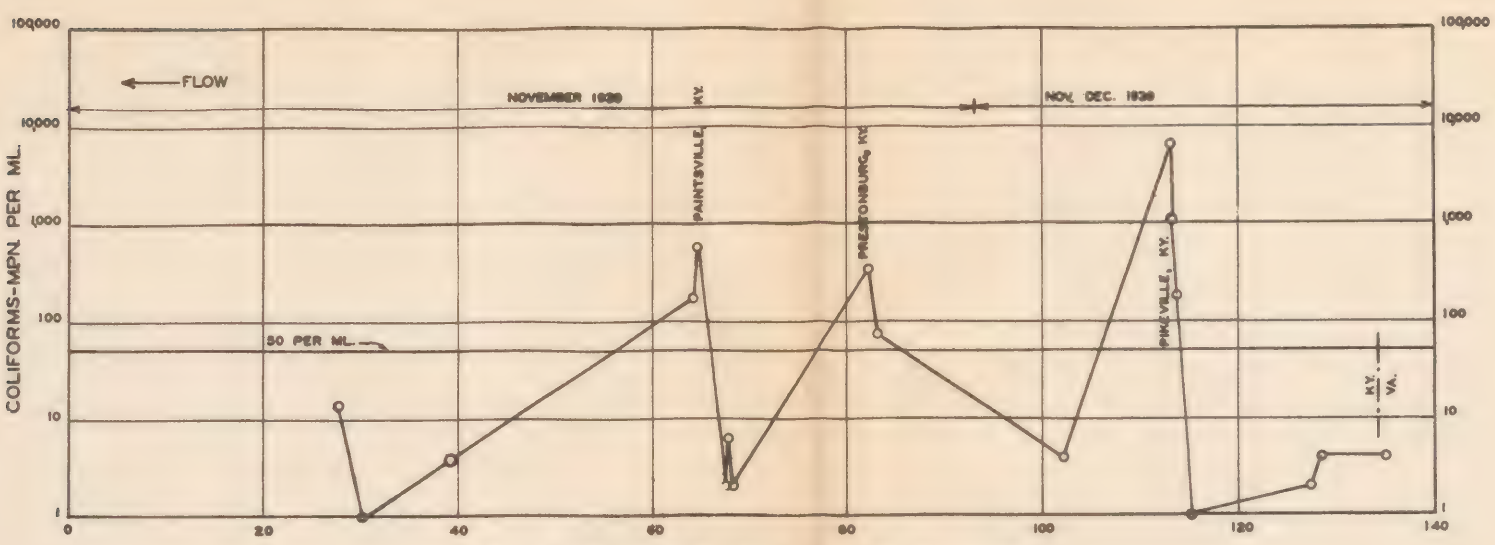
SCALE OF MILES

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

PLATE PREPARED APRIL 1, 1943



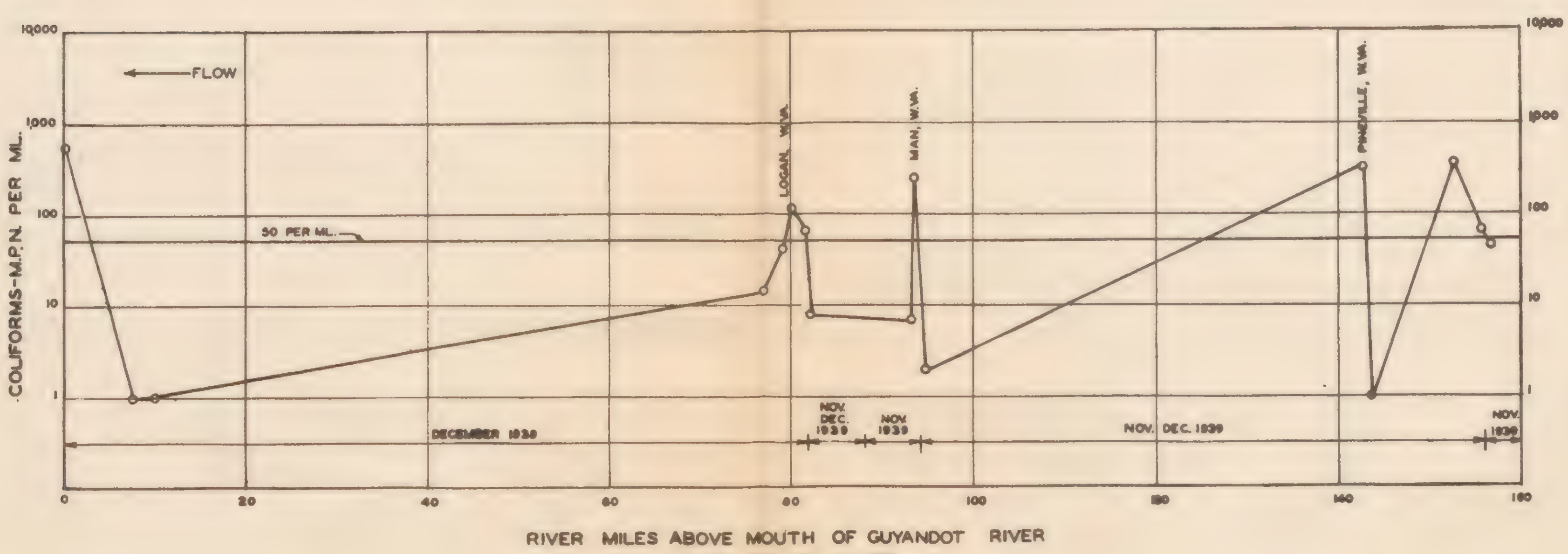
RIVER MILES ABOVE MOUTH OF BIG SANDY RIVER
BIG SANDY RIVER - TUG FORK



RIVER MILES ABOVE MOUTH OF BIG SANDY RIVER
LEVISA FORK

GUYANDOT-BIG SANDY RIVER BASINS

NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILES SHOW SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIODS REPRESENTED:
GUYANDOT RIVER-
JUNE, 1939 TO APRIL, 1940
BIG SANDY RIVER-
JUNE, 1939 TO APRIL, 1940



RIVER MILES ABOVE MOUTH OF GUYANDOT RIVER
GUYANDOT RIVER

PLATE NO 30

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

COLIFORM BACTERIA RESULTS
GUYANDOT-BIG SANDY RIVER BASINS

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

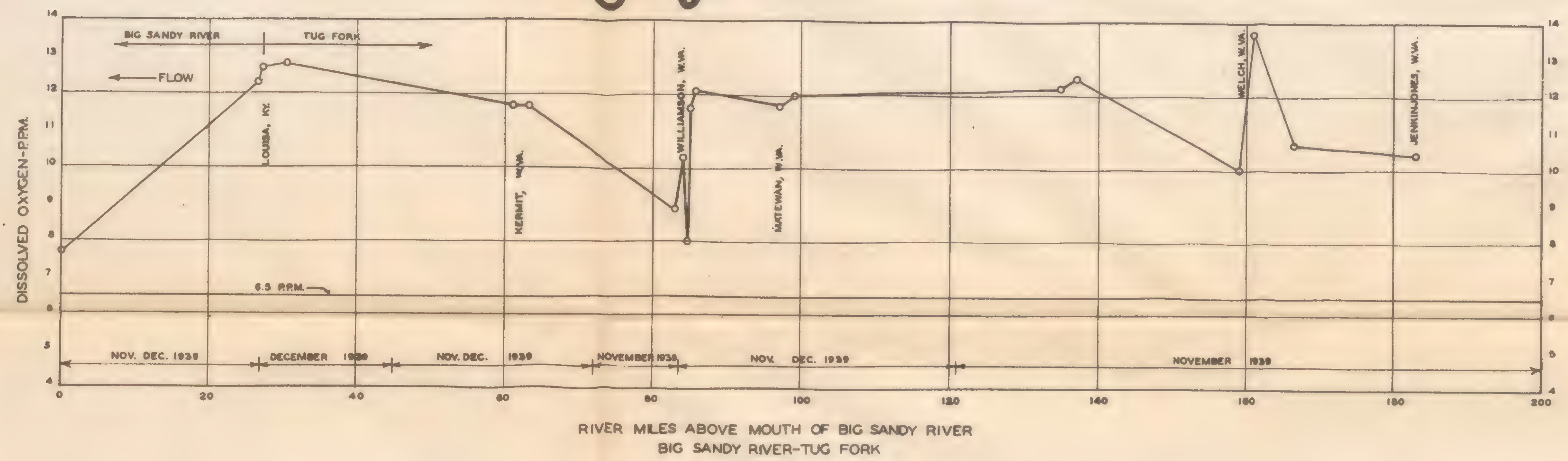
PLATE PREPARED JUNE 1, 1942

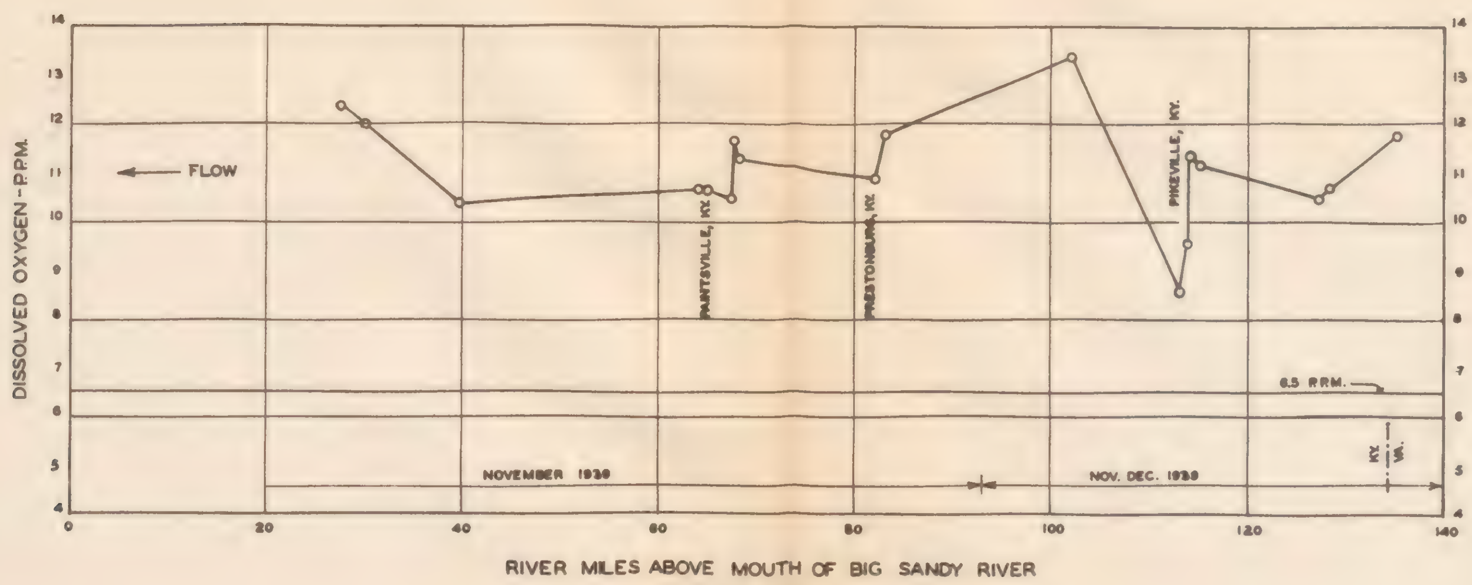
PREPARED BY U.S. PUBLIC HEALTH SERVICE

GPO-43 O-90035

LEGEND
Average Dissolved Oxygen
Results at Sampling Stations

Symbol	Dissolved Oxygen p.p.m
○	Over 6.5
◔	5.1 to 6.5
◑	3.1 to 5.0
●	0.1 to 3.0





GUYANDOT-BIG SANDY RIVER BASINS

NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILES SHOW SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIODS REPRESENTED:
GUYANDOT RIVER-
JUNE, 1939 TO APRIL, 1940
BIG SANDY RIVER-
JUNE, 1939 TO APRIL, 1940

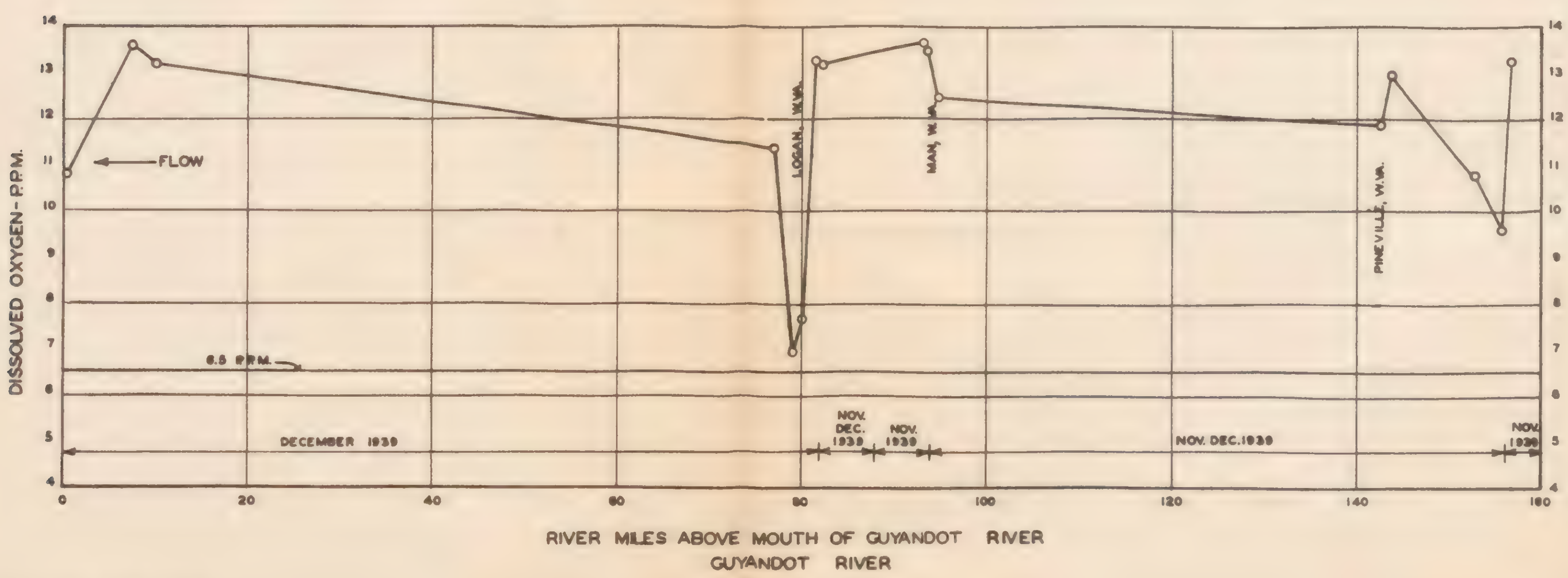


PLATE NO. 31

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

DISSOLVED OXYGEN RESULTS
GUYANDOT - BIG SANDY RIVER BASINS

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED JUNE 1, 1942

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

GPO-43 O-90035

PLATE NO. 32

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

SOURCES OF POLLUTION

SCIOTO RIVER BASIN

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

10 0 10
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED APRIL 1, 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

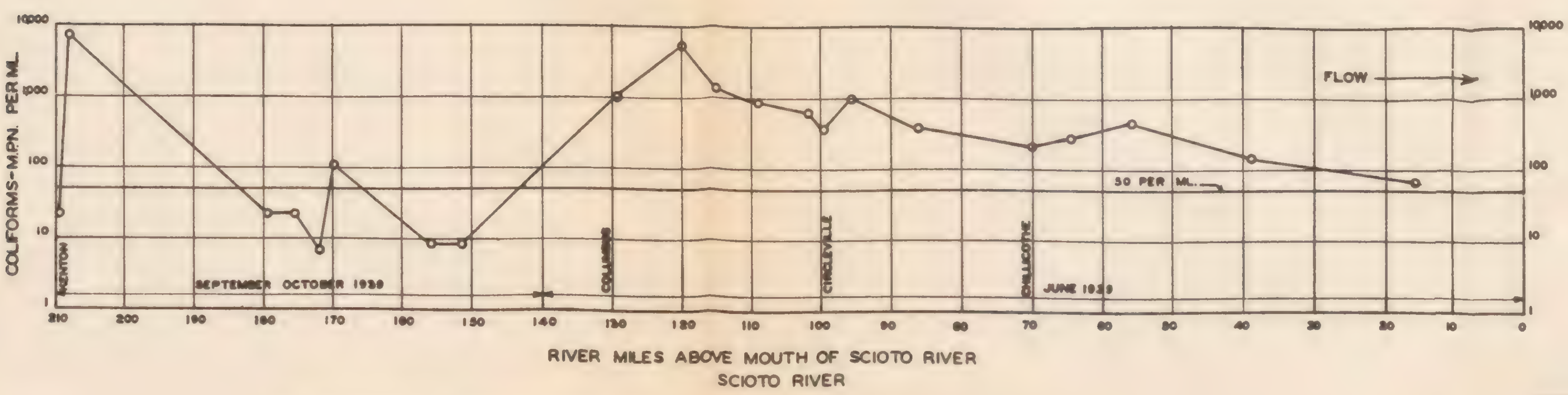
GPO-43 O-90035

NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILE SHOWS SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIOD REPRESENTED JANUARY, 1939 TO APRIL, 1940.

LEGEND

Average Coliform Results at Sampling Stations.

Symbol	Most probable number per ml.
○	Under 25
◔	25 – 50
◑	51 – 100
◕	101 – 200
●	Over 200



RIVER MILES ABOVE MOUTH OF SCIOTO RIVER
SCIOTO RIVER

SCIOTO RIVER BASIN

PLATE NO. 33

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

COLIFORM BACTERIA RESULTS SCIOTO RIVER BASIN

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

5 0 10
SCALE OF MILES

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

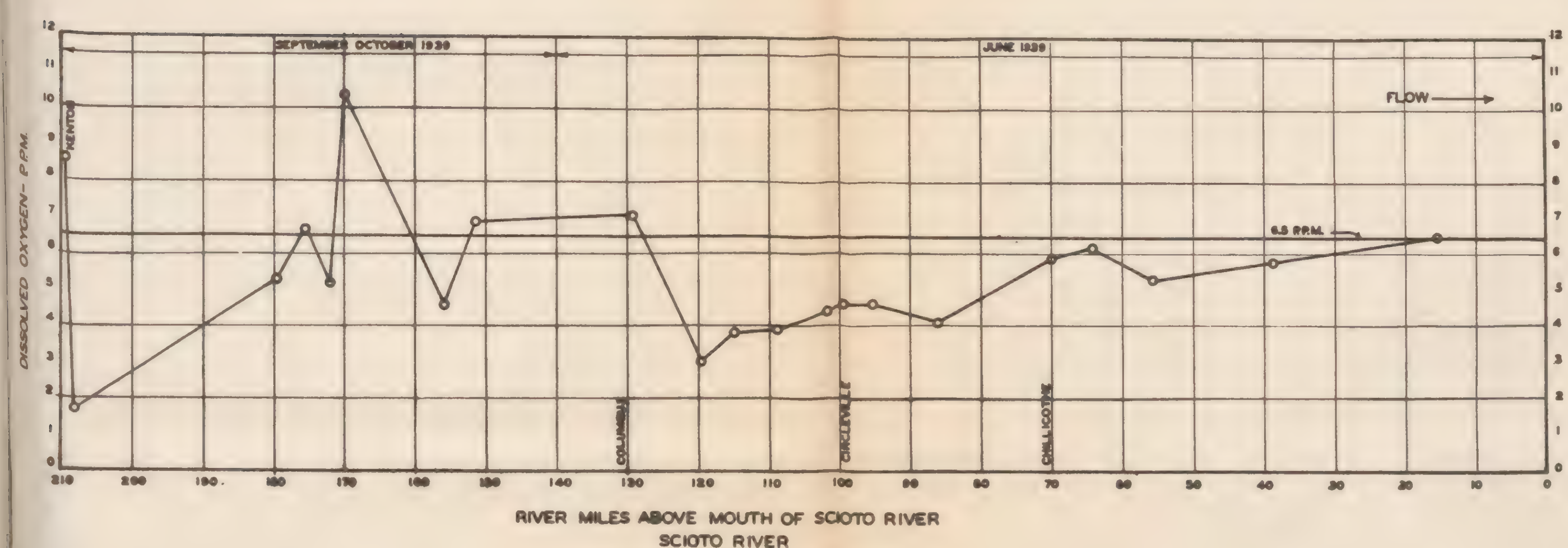
PLATE PREPARED JUNE 1, 1942

GPO-43 O-90035

NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS. AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILE SHOWS SELECTED MONTHLY AVERAGE RESULTS AS INDICATED
(3) SAMPLING PERIOD REPRESENTED JANUARY, 1939 TO APRIL, 1940.

LEGEND
Average Dissolved Oxygen Results at Sampling Station

Symbol	Dissolved Oxygen p.p.m.
○	Over 6.5
◔	5.1 to 6.5
◑	3.1 to 5.0
◕	0.1 to 3.0
●	0.0



SCIOTO RIVER BASIN

PLATE NO 34

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL
DISSOLVED OXYGEN RESULTS
SCIOTO RIVER BASIN

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

SCALE OF MILES

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

PLATE PREPARED JUNE 1, 1942

GPO-41 O-90035

PLATE NO. 35

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

SOURCES OF POLLUTION

LITTLE MIAMI - MIAMI RIVER BASINS

IN 1 SHEET | SHEET NO. 1 | SCALE: AS SHOWN

10 0 10

SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

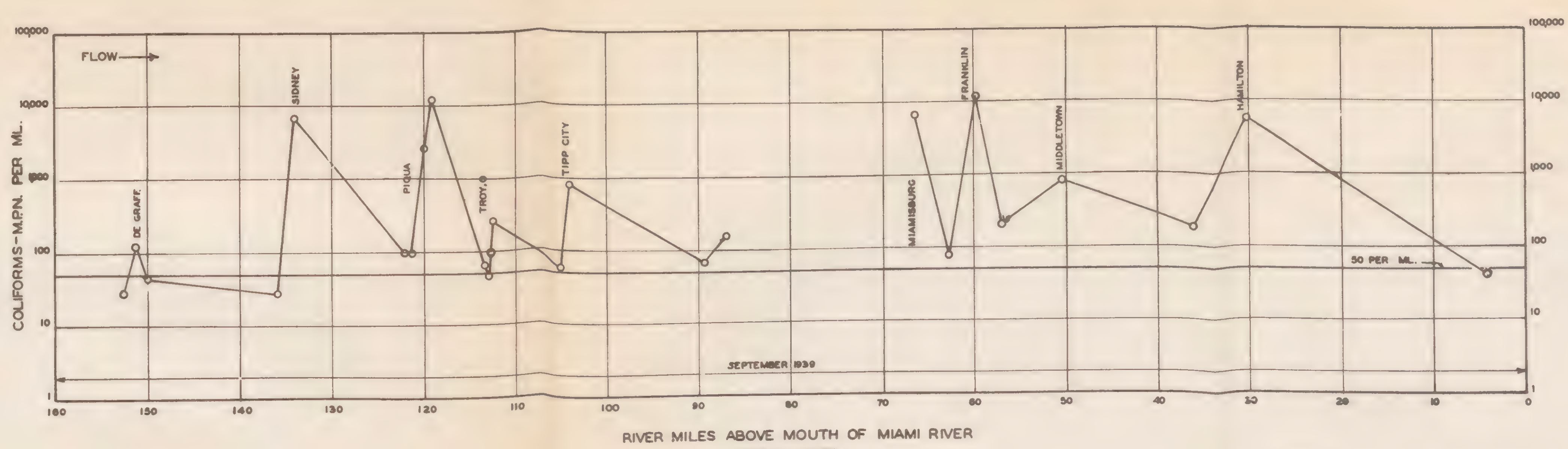
PLATE PREPARED APRIL 1, 1943

GPO-43 O-90035

LEGEND

Average Coliform Results at Sampling Stations.

Symbol	Most probable number per ml.
○ -----	Under 25
◔ -----	25- 50
◑ -----	51-100
◕ -----	101-200
● -----	Over 200



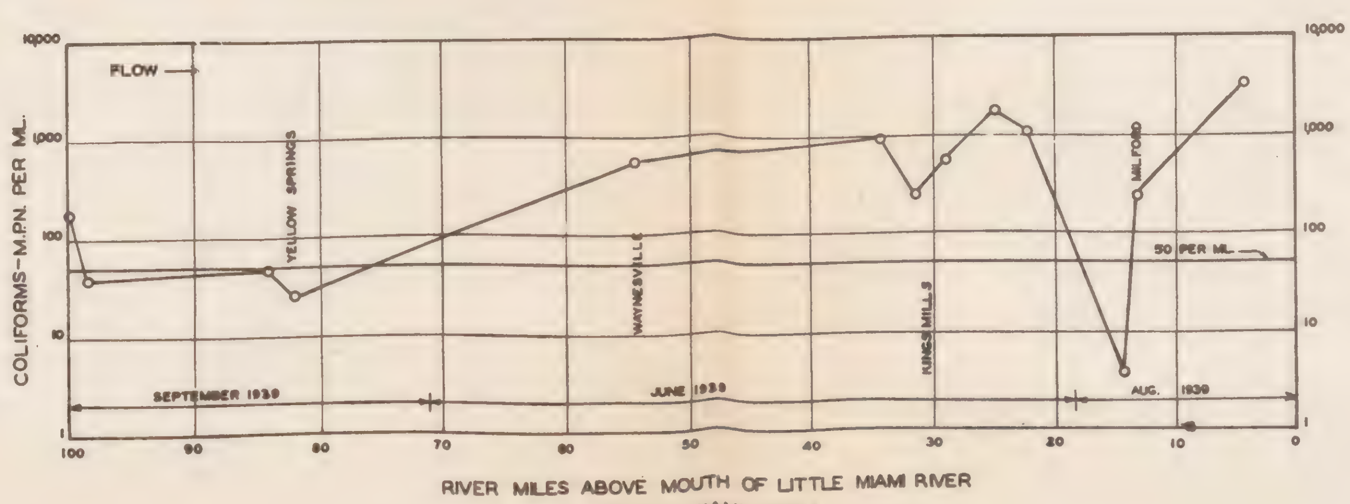
RIVER MILES ABOVE MOUTH OF MIAMI RIVER
MIAMI RIVER

NOTES:

(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.

(2) PROFILES SHOW SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.

(3) SAMPLING PERIODS REPRESENTED:
LITTLE MIAMI RIVER-
JANUARY, 1939 TO MAY, 1940
MIAMI RIVER-
FEBRUARY, 1939 TO APRIL, 1940



RIVER MILES ABOVE MOUTH OF LITTLE MIAMI RIVER
LITTLE MIAMI RIVER

PLATE NO. 36

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

COLIFORM BACTERIA RESULTS
LITTLE MIAMI-MIAMI RIVER BASINS

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

5 0 5 10
SCALE OF MILES

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

PLATE PREPARED JUNE 1, 1942

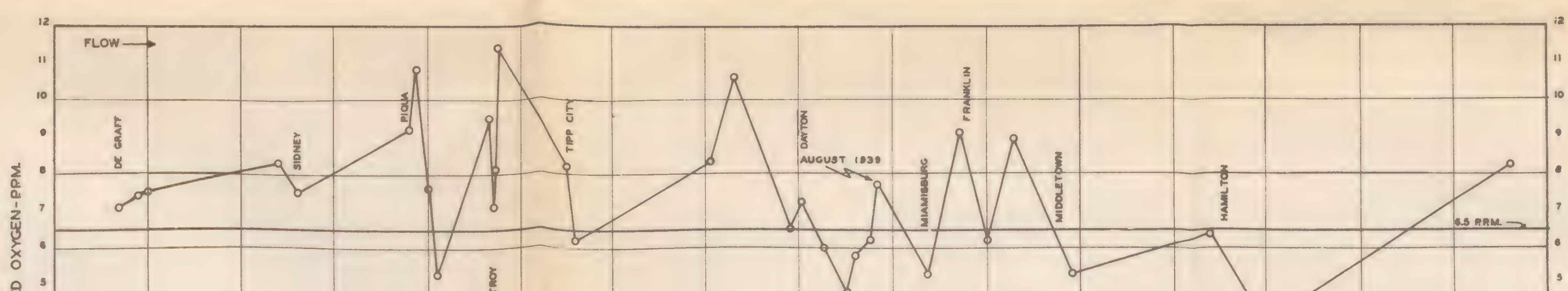
LITTLE MIAMI-MIAMI RIVER BASINS

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

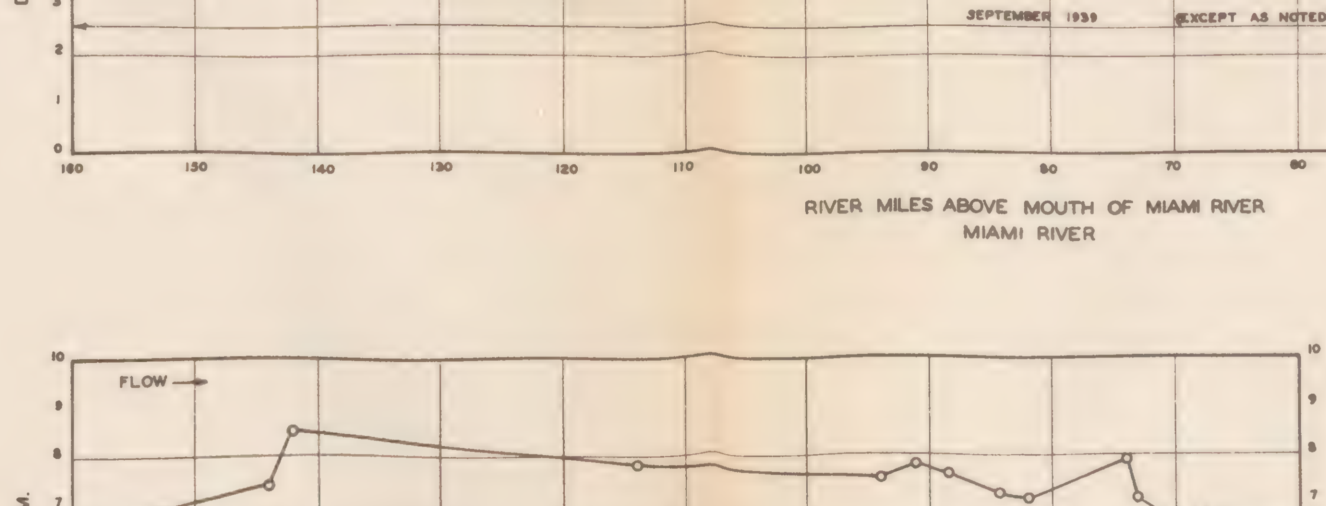
GPO-43 O-90035

LEGEND
Average Dissolved Oxygen Results at Sampling Stations.

Symbol	Dissolved Oxygen p.p.m.
○	Over 6.5
◔	5.1 to 6.5
◑	3.1 to 5.0
●	0.1 to 3.0
◉	0.0



RIVER MILES ABOVE MOUTH OF MIAMI RIVER
MIAMI RIVER



RIVER MILES ABOVE MOUTH OF LITTLE MIAMI RIVER
LITTLE MIAMI RIVER

NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILES SHOW SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIODS REPRESENTED:
LITTLE MIAMI RIVER – JANUARY, 1939 TO MAY, 1940
MIAMI RIVER – FEBRUARY, 1939 TO APRIL, 1940

LITTLE MIAMI-MIAMI RIVER BASINS

PLATE NO. 37

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

DISSOLVED OXYGEN RESULTS LITTLE MIAMI-MIAMI RIVER BASINS

IN 1 SHEET SHEET NO. 1 SCALE AS SHOWN

SCALE OF MILES: 5 0 5 10

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

PLATE PREPARED JUNE 1, 1942

GPO-43 O-90035

PLATE NO. 38

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

SOURCES OF POLLUTION
LICKING-KENTUCKY-SALT RIVER BASINS

IN I SHEET — SHEET NO. I — SCALE AS SHOWN

10 0 10
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

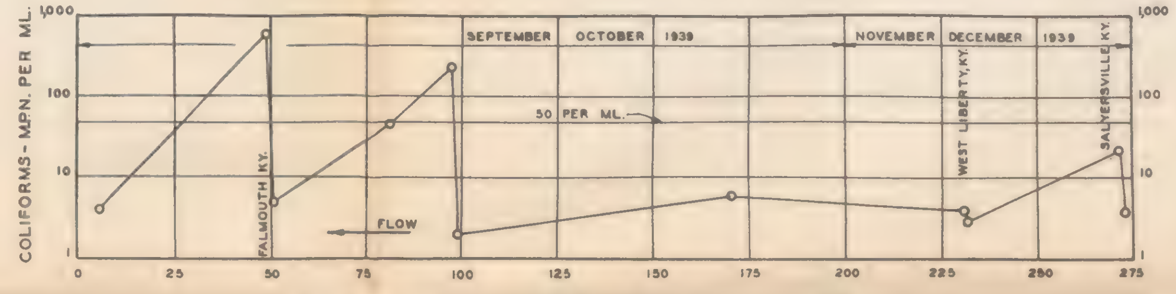
PLATE PREPARED APRIL 1, 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

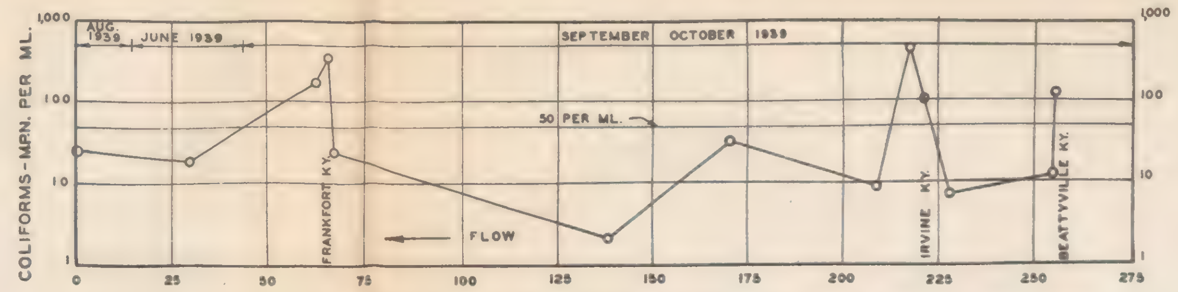
GPO-43 O-90035

NOTES:
1 MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIOD OF LESS THAN 30 DAYS AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS
2 PROFILES SHOW SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
3 SAMPLING PERIODS REPRESENTED:
LICKING RIVER - FEBRUARY 1939 TO MARCH 1940
KENTUCKY RIVER - MARCH TO DECEMBER 1939
FEBRUARY TO APRIL JULY & OCTOBER 1940 JANUARY 1941
SALT RIVER - JULY AUGUST OCTOBER 1940 FEBRUARY 1941

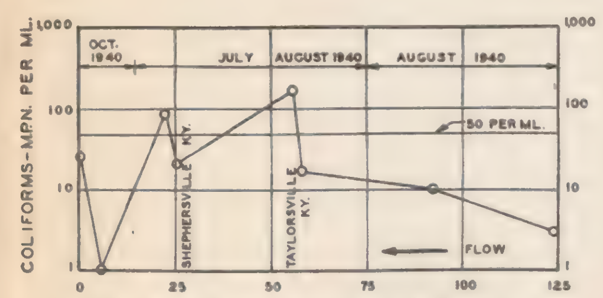
LICKING-KENTUCKY-SALT RIVER BASINS



LICKING RIVER



KENTUCKY RIVER



SALT RIVER

PLATE NO. 39

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

COLIFORM BACTERIA RESULTS

LICKING-KENTUCKY-SALT RIVER BASINS

IN 1 SHEET | SHEET NO 1 | SCALES AS SHOWN

10 0 10 20
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED: APRIL 1, 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

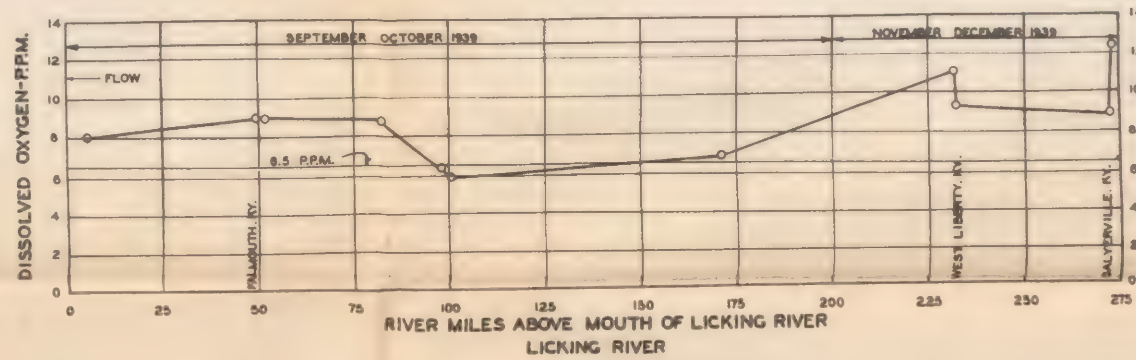
GPO-43 O-90035

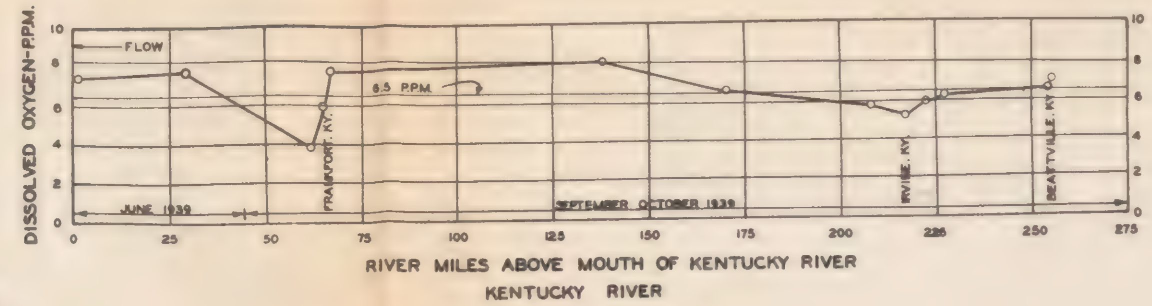
LEGEND

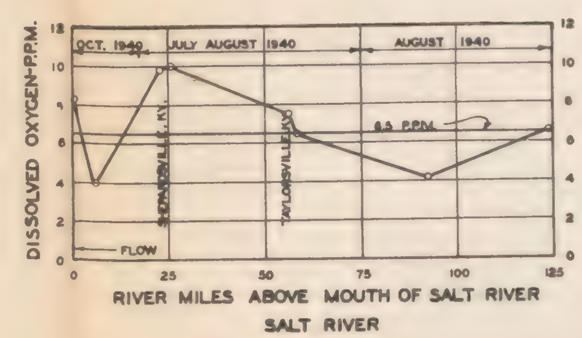
AVERAGE DISSOLVED OXYGEN RESULTS AT SAMPLING STATIONS

SYMBOL DISSOLVED OXYGEN P.P.M.

- ○ ------OVER 6.5
- ◔ ------5.1 TO 6.5
- ◑ ------3.1 TO 5.0
- ● ------0.1 TO 3.0
- ● ------ 0.0







NOTES:
1. MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
2. PROFILES SHOW SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
3. SAMPLING PERIODS REPRESENTED:
   LICKING RIVER-FEBRUARY 1939 TO MARCH 1940;
   KENTUCKY RIVER-MARCH TO DECEMBER 1939; FEBRUARY TO APRIL, JULY & OCTOBER 1940; JANUARY 1941.
   SALT RIVER-JULY, AUGUST, OCTOBER 1940; FEBRUARY 1941.

LICKING-KENTUCKY-SALT RIVER BASINS

PLATE NO. 40

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

DISSOLVED OXYGEN RESULTS

LICKING-KENTUCKY-SALT RIVER BASINS

IN 1 SHEET — SHEET NO.1 — SCALES AS SHOWN

10 0 10 20

SCALE OF MILES

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

PLATE PREPARED: APRIL 1, 1943

MAP PREPARED BY U. S. PUBLIC HEALTH SERVICE

GPO-43 O-90035

PLATE NO. 41

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

SOURCES OF POLLUTION

GREEN–CUMBERLAND RIVER BASINS

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

10 0 10 20 30
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

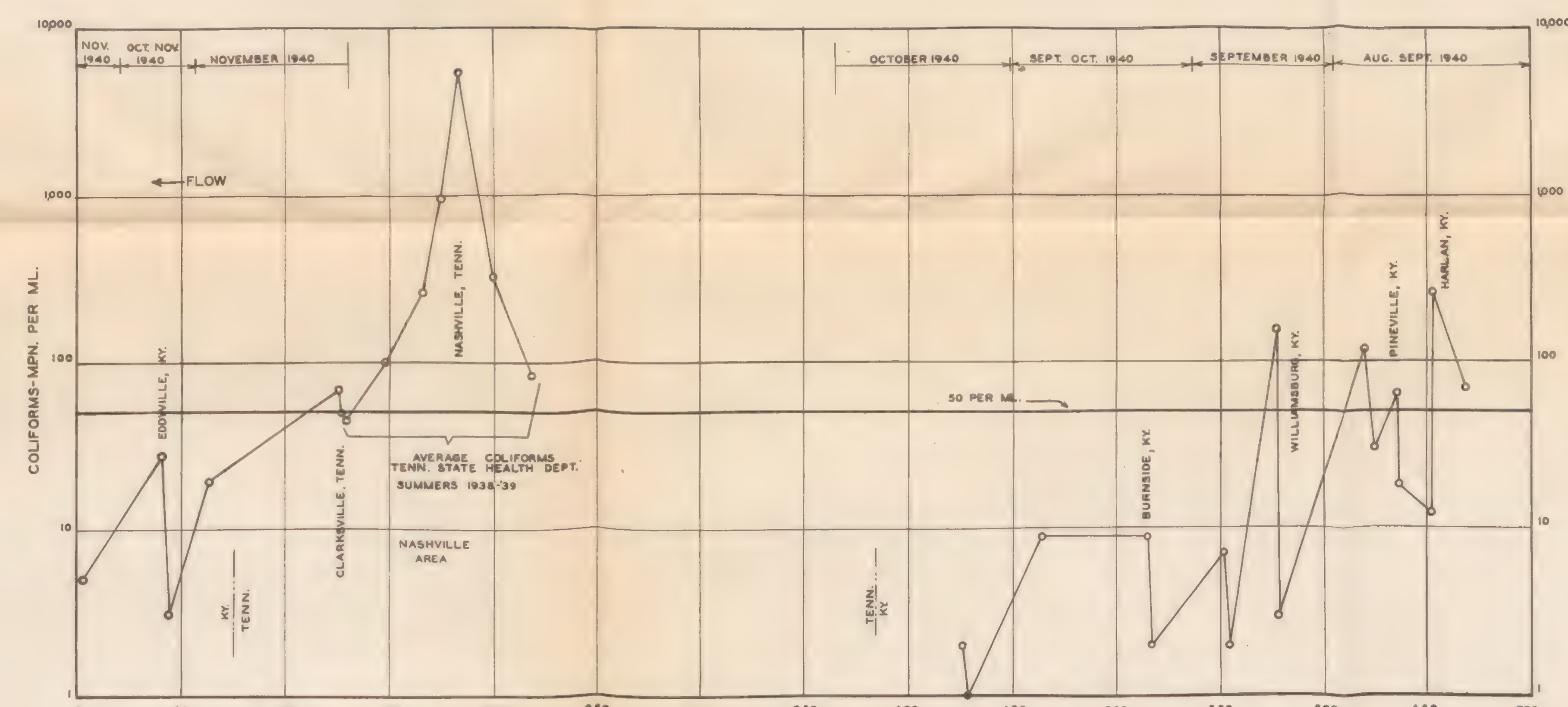
PLATE PREPARED APRIL 1, 1943

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

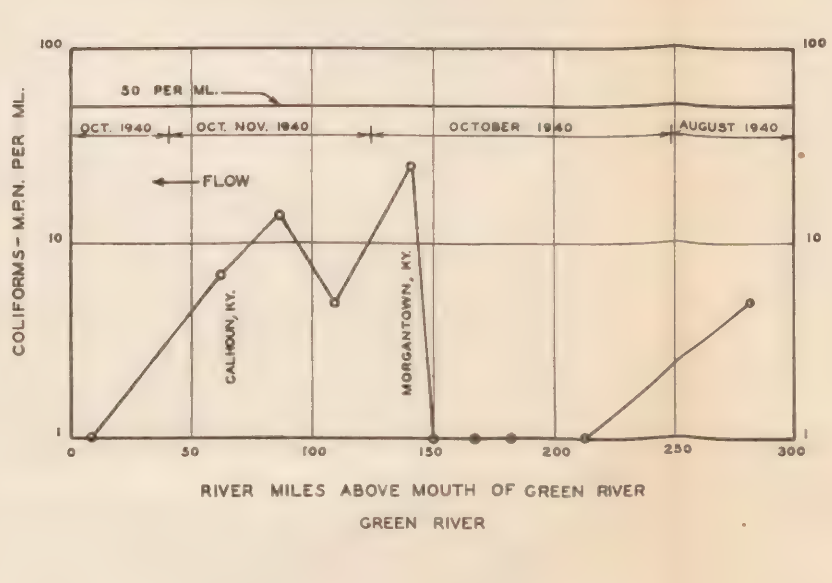
GPO-43 O-88835

LEGEND
Average Coliform Results
at Sampling Stations

Symbol	Most probable number per ml.
○	Under 25
◔	25 - 50
◑	51 - 100
◕	101 - 200
●	Over 200
⊢○	Tennessee Health Department Data



NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILES SHOW SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIODS REPRESENTED:
GREEN RIVER–
AUGUST TO NOVEMBER, 1940.
FEBRUARY, 1941.
CUMBERLAND RIVER–
AUGUST TO NOVEMBER, 1940.
JANUARY TO MARCH, 1941.



GREEN-CUMBERLAND RIVER BASINS

PLATE NO 42

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL
COLIFORM BACTERIA RESULTS
GREEN-CUMBERLAND RIVER BASINS

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

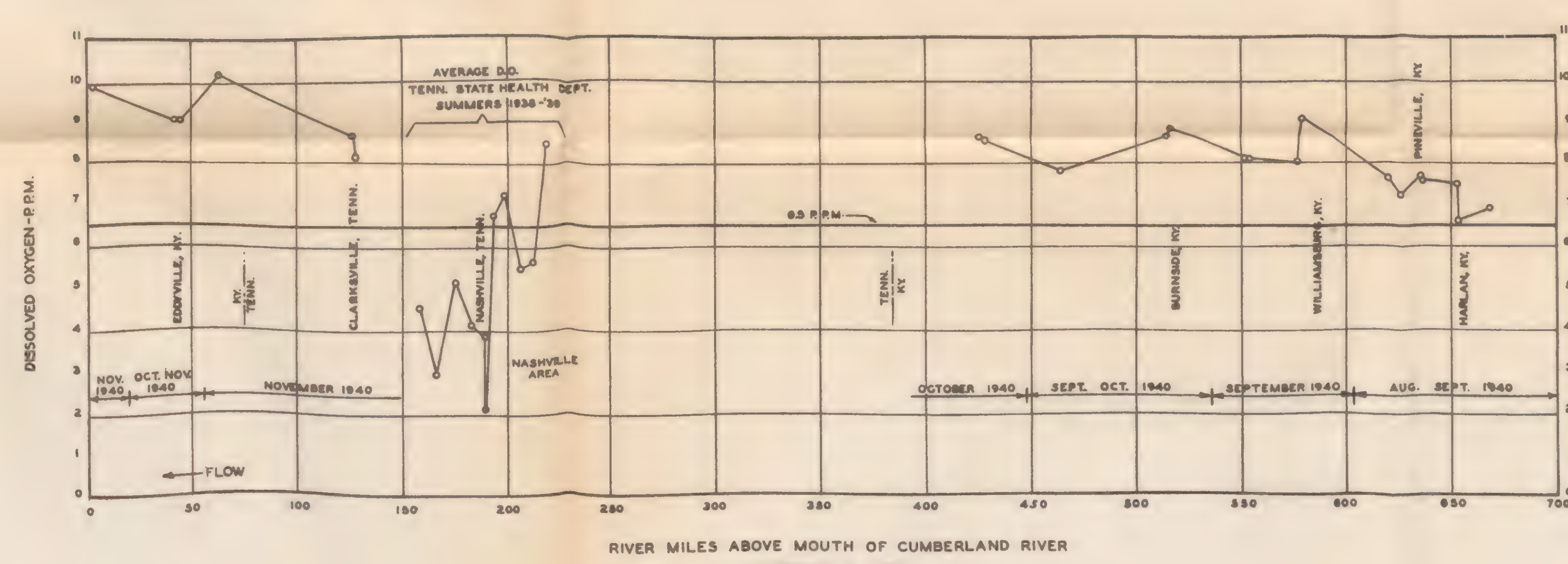
10 0 10 20 30
SCALE OF MILES

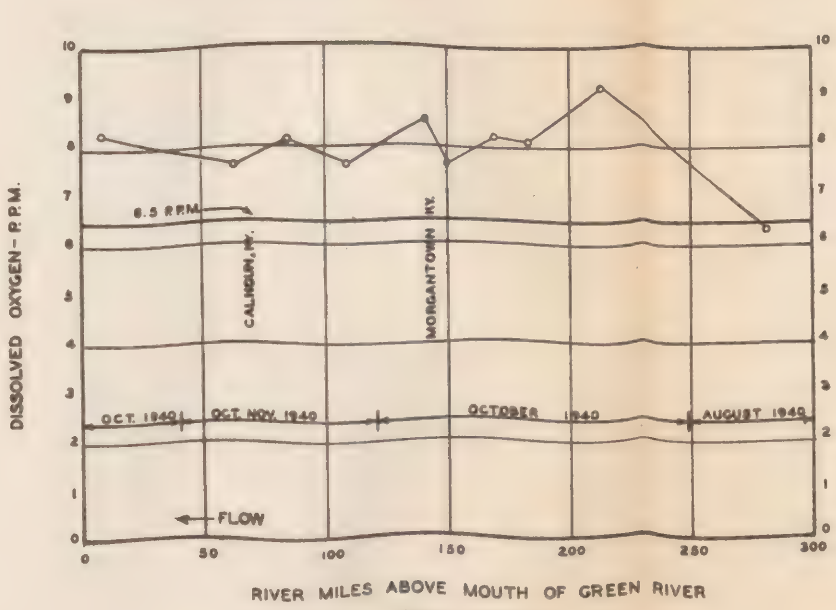
TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED JUNE 1, 1942

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

GPO-43 O-90035





GREEN-CUMBERLAND RIVER BASINS

NOTES:

(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.

(2) PROFILES SHOW SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.

(3) SAMPLING PERIODS REPRESENTED:
GREEN RIVER-
AUGUST TO NOVEMBER, 1940.
FEBRUARY, 1941.
CUMBERLAND RIVER-
AUGUST TO NOVEMBER, 1940.
JANUARY TO MARCH, 1941

PLATE NO 43

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL
DISSOLVED OXYGEN RESULTS
GREEN-CUMBERLAND RIVER BASINS

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

10 0 10 20 30
SCALE OF MILES

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

PLATE PREPARED JUNE 1, 1942

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

GPO-43 O-80035

WAR DEPARTMENT

CORPS OF ENGINEERS, U.S. ARMY

PLATE NO. 44

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

SOURCES OF POLLUTION
WABASH RIVER BASIN

IN 1 SHEET | SHEET NO. 1 | SCALE AS SHOWN

10 0 10 20
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

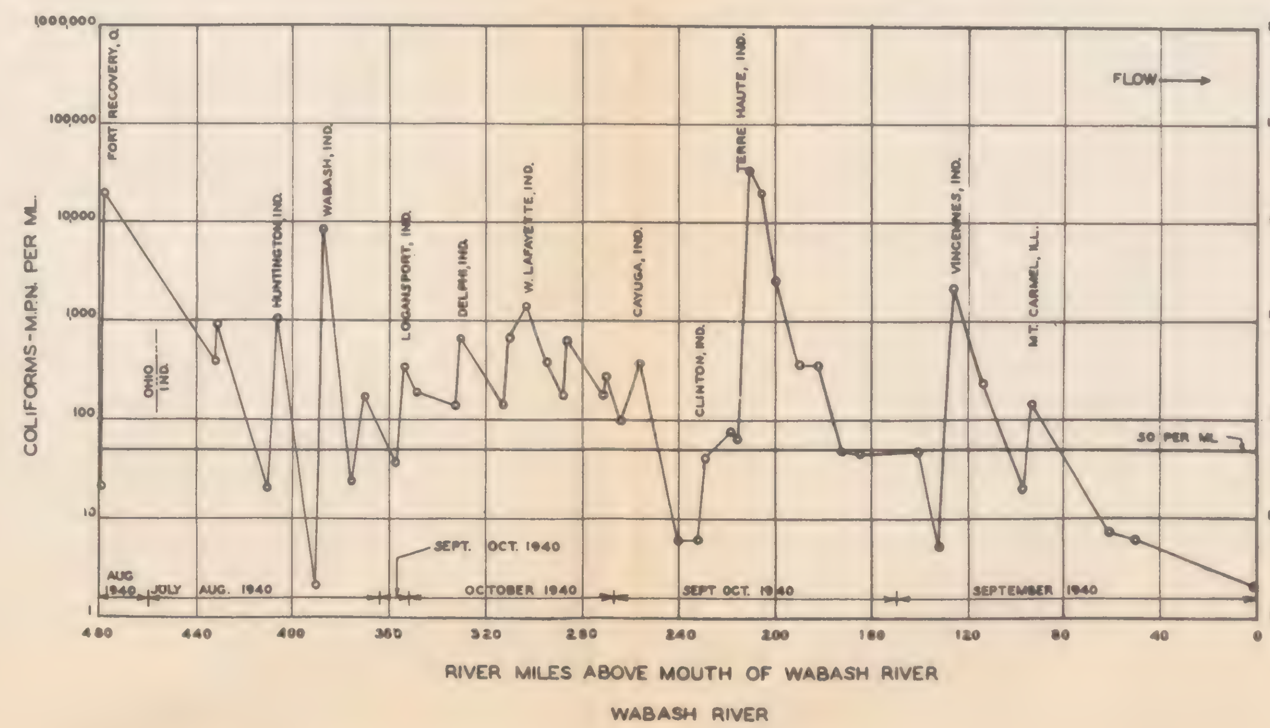
PLATE PREPARED APRIL 1, 1943

GPO-43 O-80035

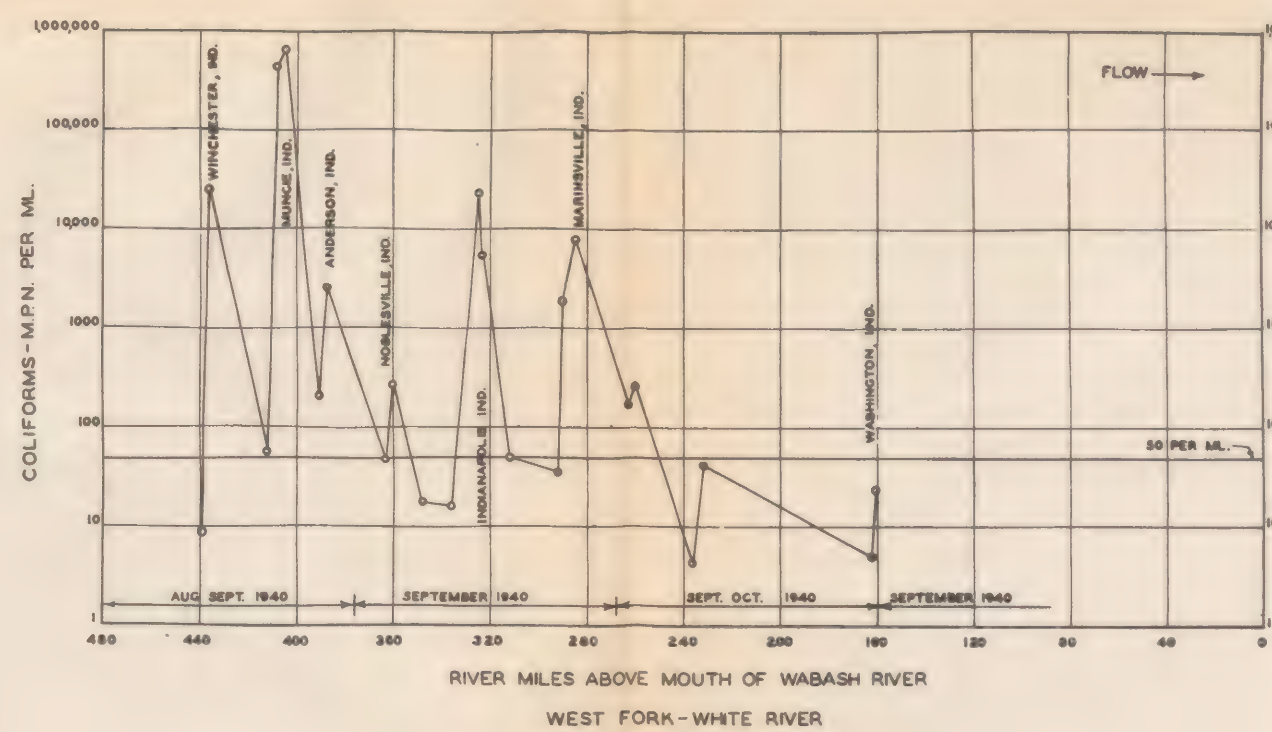
WABASH RIVER BASIN

LEGEND
Average Coliform Results at Sampling Stations

Symbol	Most probable number per ml.
○	Under 25
◔	25 - 50
◑	51 - 100
◕	101 - 200
●	Over 200



WABASH RIVER



WEST FORK-WHITE RIVER

NOTES:
(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.
(2) PROFILES SHOW SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.
(3) SAMPLING PERIODS REPRESENTED: JULY TO NOVEMBER, 1940. FEBRUARY, 1941.

PLATE NO. 45

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

COLIFORM BACTERIA RESULTS WABASH RIVER BASIN

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

SCALE OF MILES 10 0 10 20

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

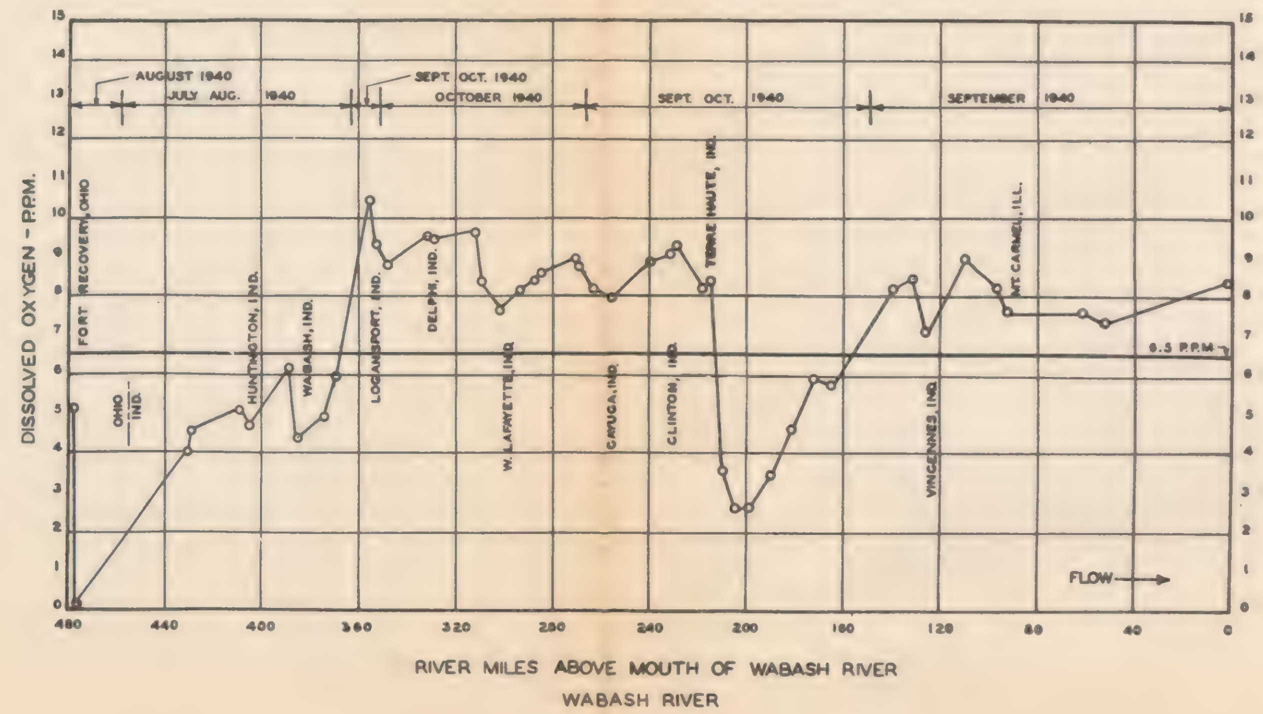
PLATE PREPARED JUNE 1, 1942

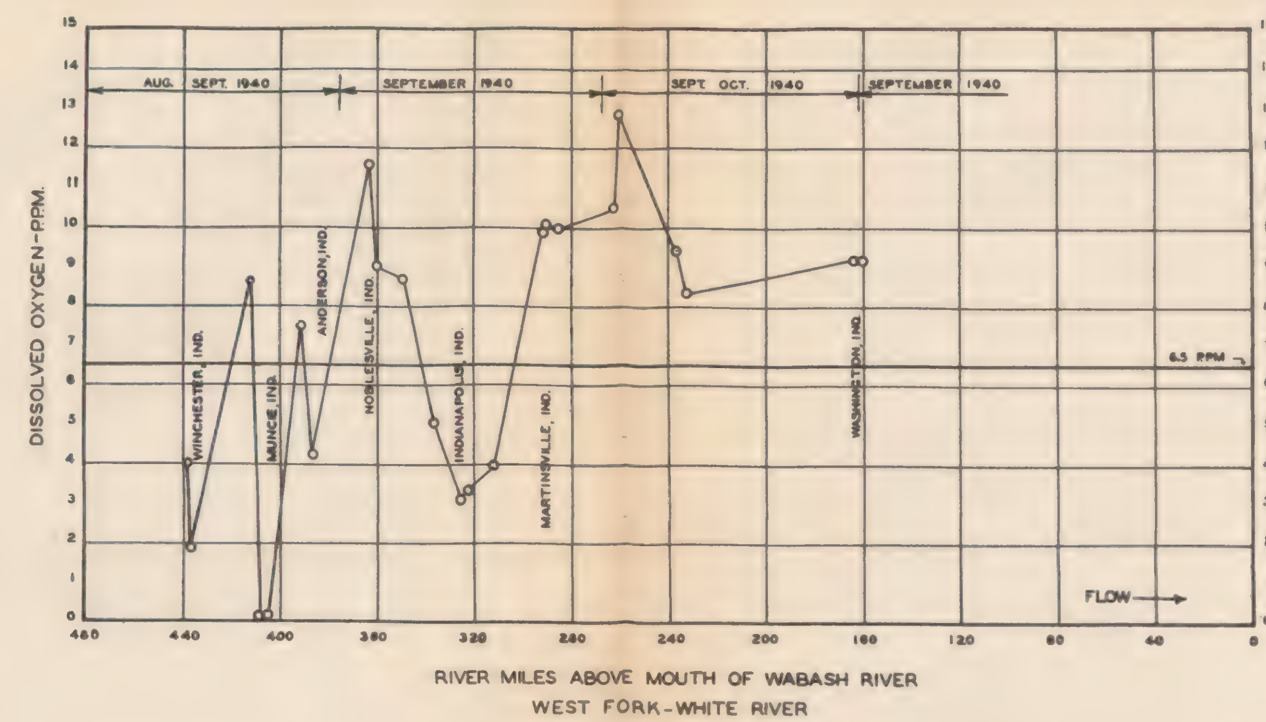
MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

GPO-43 O-00035

LEGEND
Average Dissolved Oxygen
Results at Sampling Stations.

Symbol	Dissolved Oxygen p.p.m.
○	Over 6.5
◔	5.1 to 6.5
◑	3.1 to 5.0
●	0.1 to 3.0
●	0.0





NOTES:

(1) MAP SHOWS AVERAGE RESULTS AT STATIONS OBSERVED FOR PERIODS OF LESS THAN 30 DAYS, AND MOST UNFAVORABLE MONTHLY AVERAGE RESULTS AT STATIONS OBSERVED FOR LONGER PERIODS.

(2) PROFILES SHOW SELECTED MONTHLY AVERAGE RESULTS AS INDICATED.

(3) SAMPLING PERIODS REPRESENTED: JULY TO NOVEMBER, 1940 FEBRUARY, 1941.

PLATE NO. 46

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

DISSOLVED OXYGEN RESULTS WABASH RIVER BASIN

IN 1 SHEET — SHEET NO. 1 — SCALE AS SHOWN

10 0 10 20
SCALE OF MILES

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

PLATE PREPARED JUNE 1, 1942

GPO-43 0-98035

PLATE NO. 47

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

SOURCES OF POLLUTION

TENNESSEE RIVER BASIN

IN 1 SHEET | SHEET NO. 1 | SCALE AS SHOWN

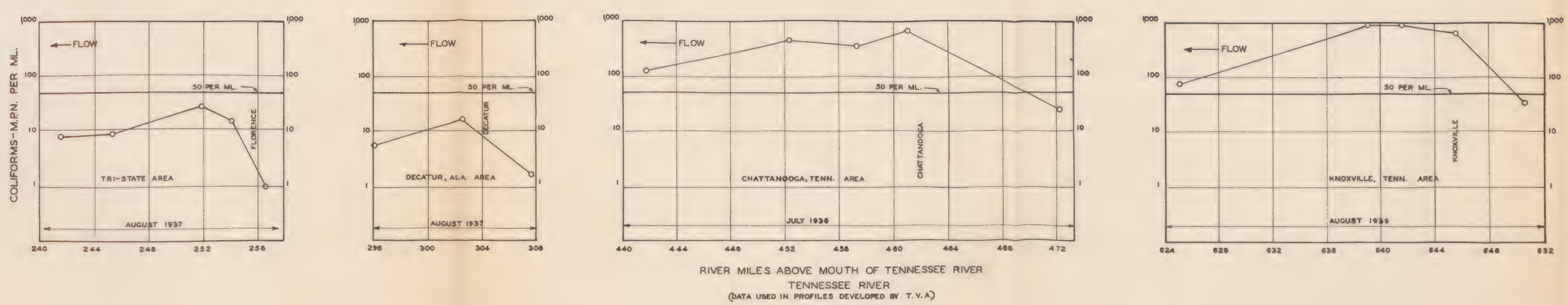
10 0 10 20 30
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED APRIL 1, 1943

WAR DEPARTMENT

CORPS OF ENGINEERS, U.S. ARMY



TENNESSEE RIVER BASIN

PLATE NO. 46

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL

COLIFORM BACTERIA RESULTS
TENNESSEE RIVER BASIN

IN 1 SHEET — SHEET NO 1 — SCALE AS SHOWN

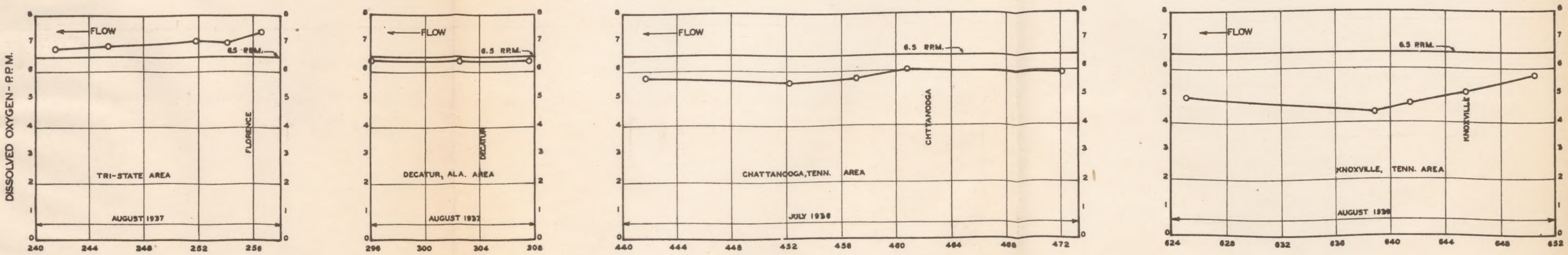
SCALE OF MILES

TO ACCOMPANY REPORT OF THE OHIO RIVER COMMITTEE TO THE SECRETARY OF WAR

MAP PREPARED BY U. S. PUBLIC HEALTH SERVICE

PLATE PREPARED JUNE 1, 1942

GPO-43 O-90035



RIVER MILES ABOVE MOUTH OF TENNESSEE RIVER
TENNESSEE RIVER

(DATA USED IN PROFILES DEVELOPED BY T.V.A.)

TENNESSEE RIVER BASIN

PLATE NO. 48

SURVEY OF THE OHIO RIVER AND ITS TRIBUTARIES FOR POLLUTION CONTROL
DISSOLVED OXYGEN RESULTS
TENNESSEE RIVER BASIN

IN 1 SHEET | SHEET NO. 1 | SCALE AS SHOWN

10 0 10 20 30
SCALE OF MILES

TO ACCOMPANY
REPORT OF THE OHIO RIVER
COMMITTEE TO THE SECRETARY
OF WAR

PLATE PREPARED JUNE 1, 1942

MAP PREPARED BY U.S. PUBLIC HEALTH SERVICE

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